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PHYSICS.—*The measurement of some thermal properties of water.*[1]

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At the end of the eighteenth century it was shown that heat was not a substance but a form of energy. In a report in 1798 Count Rumford described an experiment, made while boring a cannon, where sufficient heat was developed with a blunt tool in two and one-half hours to raise the temperature of 26.5 pounds of cold water to its boiling point, although in doing so less than 0.6 of a pound of metal was removed. This evidence proved *almost* conclusively that heat was a form of energy. A more conclusive proof, however, was given in 1799 when Sir Humphry Davy described an experiment in which he melted ice by rubbing two blocks of it together.

Since it was shown that heat was a form of energy, it was rather natural that the unit of heat energy was defined at first in terms of the properties of water. The unit of heat was taken as the energy necessary to heat a unit mass of water 1°. In the metric system the units were the energy necessary to raise a gram, or a kilogram, of water 1°C. and were called the gram calorie, and kilogram calorie, respectively. In the English system the unit was the heat necessary to raise a pound of water 1°F. and was called the British thermal unit (BTU). The unit of heat defined in terms of water was very convenient because most calorimetric measurements were made in terms of the heat capacity of water, and also because the specific heat of water changes little with temperature. When the precision of measurement had increased, and it was shown that the specific heat of water did vary with temperature, it became necessary to define the heat unit more precisely. This led to the use of different calories, known as the 0° calorie, the 4°, 15°, 18°, 20° calorie and also the mean calorie, which was the mean between 0° and 100°C.

About 1830 Sadi Carnot had estimated the heat unit to be equivalent to 370 kilogram meters, which is about 13 percent lower than the present accepted value. Carnot had planned to determine the heat unit experimentally, but his early death in 1836 stopped these experiments.

James Prescott Joule (*1*)[2] appears to be the first to have made systematic measurements of the mechanical equivalent of heat. His experiments began about 1840 and continued up to 1878. He made these experiments with different substances to show that heat was a form of energy quite independent of the substance which was heated. The mechanical equivalent of heat, or Joule's equivalent, subsequently has been denoted by the letter "J." As a further tribute to Joule, all science now honors him by the use of his name for a unit of energy.

Henry A. Rowland (*2*), in his painstaking way, made experiments on the mechanical equivalent with an apparatus similar in design to Joule's but with Rowland's characteristic attention to detail. These experiments were made in the range from 5° to 35°C. in order to study the variation of the specific heat of water with temperature. At the conclusion of his paper, published in 1878, he modestly stated that "between the limits of 15° and 25°C., I feel almost certain that no subsequent experiments will change my values of the equivalent so much as two parts in 1,000." This modest claim seems to be fully substantiated by recent experiments.

[1] Address of the retiring president of the Philosophical Society of Washington, delivered at the 1242d meeting of the Society, January 6, 1945. Received February 26, 1945.

[2] Italic numbers in parenthesis refer to literature cited at the end of this paper.

A classical determination of the mechanical equivalent of the mean thermal unit between 0° and 100°C. was published in 1897 by Osborne Reynolds and W. H. Moorby (*3*). Reynolds was the engineer, famous for his researches on fluid motions, with whose name is associated the dimensionless numbers which describe the states of fluid flow. These men used power from a 65 horsepower steam engine for heating a continuous flow of water in a hydraulic brake of Reynolds's design.

This short list of researches on the mechanical equivalent of heat would be incomplete without mention of the relatively recent determination by Laby and Hercus (*4*), published in 1927. In their ingenious apparatus they made use of a flow calorimeter in which heat was produced by electric currents induced by a rotating electromagnet. The energy was measured mechanically by determining the couple in much the same way that Joule and Rowland measured it. This was done by refined methods which justify their claim to "the highest precision attainable with the present developments of physical technique." This research may well be the last classical experiment to determine the mechanical equivalent of heat *directly*, because the indirect method of measuring energy electrically not only is much more convenient but is also more accurate.

At present the ratio of the electric units of energy to the mechanical unit is known to a considerably greater accuracy than the ratio of the heat unit to the Joule. For this reason, present-day experiments in calorimetry are usually arranged to measure electric energy directly, as it is added to the calorimeter and its contents, rather than to determine the energy by exchanging heat with water. This development removes the need for a heat unit different from the mechanical unit but does not dispel interest in the thermal properties of water.

During the period when the accuracy of the electric units was increasing, however, some pioneers made measurements of the heat unit by supplying the energy to water electrically. Notable among these pioneers are Dieterici, Griffiths, and Schuster and Gammon.

These researches were followed by another, reported in 1902 by Callendar (*5*) and by Barnes (*6*), on measurements made with a continuous flow calorimeter "on the capacity for heat of water between the freezing and boiling points." These measurements of the heat caapcity of water were more comprehensive than any of the other measurements up to that time. In 1899 and 1900 Dr. Barnes, on 54 days, made measurements at mean temperatures ranging from 1.35° to 91.55°C. Four runs were usually made on each day at two rates of flow, one high rate and one low rate, in order to make corrections for the heat losses due to radiation and conduction. These rates were varied over a ratio of nearly 2 to 1, and the heat losses varied from a little over 1.5 percent for the large flow at the lowest temperature up to nearly 6 percent of the energy input for the small flow at the highest temperature. Dr. Barnes (*7*), in 1909, estimated an accuracy for his determinations of 1 part in 10,000 over the entire range, but recent measurements suggest the possibility of some unsuspected systematic errors in his results.

In 1921 Jaeger and von Steinwehr (*8*) reported on "the heat capacity of water between 5° and 50°C. in international watt seconds." They used an electric heating method at a time when the units and standards were much better known than when Barnes made his measurements. An accuracy of 1 part in 5,000 was claimed for the heat capacity of water at 15°C.

A new series of researches on the properties of water was planned at a conference (*9*) of engineers and physicists held in Cambridge, Mass., on June 23, 1921. This conference was sponsored by the American Society of Mechanical Engineers for the purpose of obtaining accurate data on the properties of water, which would form the basis of more reliable steam tables with which the engineers could design their turbines. Prof. Harvey N. Davis at Harvard University agreed to complete measurements he had started on the Joule-Thomson coefficient of steam. Prof. Frederick G. Keyes at the Massachusetts Institute of Technology (M.I.T.) undertook measurements on the pressure-volume-temperature

relations of steam. The first request to the National Bureau of Standards (N.B.S.) was to determine the mean heat unit.

The late Nathan S. Osborne accepted this responsibility but proposed to go much further by determining not only the heat of the liquid but also the heat of vaporization of water over a wide range of temperature. It is to him that the principal part of this discussion is dedicated. His genius and vision, coupled with his earlier experience in calorimetry, made the successful completion of this work possible. His experience had taught him not to go ahead blindly with the design of a calorimeter which would merely be a copy of previous calorimeters, but first to study the thermodynamics of the experiments that could be performed in the laboratory. This study proved to be a master stroke for it developed the principle of a systematic method of fluid calorimetry. The theory of this method was first published by Osborne (*10*) in April 1924 under the title of "Calorimetry of Saturated Fluids," where the term *saturated* restricts the calorimetry to experiments in which both liquid and vapor are always present.

The method makes use of a single calorimetric apparatus with which a system of measurements may be made to determine some of the essential thermal properties of a fluid, in particular the enthalpy $H=U+pv$ where U is the internal energy of the substance, p the pressure, and v the specific volume of the substance. The calorimeter is provided with two outlet tubes, one at the bottom for introducing or withdrawing liquid and the other at the top for withdrawing vapor. Valves are provided, on these tubes, for sealing fluid in the calorimeter and for controlling the rate at which fluids are withdrawn. The calorimeter is surrounded with an envelope the temperature of which is controlled to prevent any net exchange of heat with the calorimeter. All experiments are made with both liquid and vapor in the calorimeter when the properties of saturated fluids are being investigated.

The essentials of this method are as follows. First consider two experiments (*a*) and (*b*) with the same calorimeter, (*a*) with a large amount of liquid and some vapor to maintain the saturation state and (*b*) with a small amount of liquid. In these two experiments the calorimeter contains the masses of fluid M_a and M_b, respectively, and the quantities of energy Q_a and Q_b are found necessary to heat the calorimeter and its contents from the same initial temperature, t_1, to the same final temperature t_2. The difference of the energies, Q_a-Q_b, is used to heat the difference of the masses of the fluid contents, M_a-M_b, from one temperature to the other. The quotient of these differences would be equal to the change in enthalpy, H, of the liquid, were it not for the extra vapor in experiment (*b*). This requires a correction term $-L\dfrac{v}{v'-v}$ where L is the latent heat of vaporization and v and v' are the specific volumes of the saturated liquid and vapor respectively. This gives the equation:

$$\frac{Q_a-Q_b}{M_a-M_b}=\left[H-L\frac{v}{v'-v}\right]_{t_1}^{t_2}=[\alpha]_{t_1}^{t_2}.$$

The quantity $H-L\dfrac{v}{v'-v}$ in this equation is a specific energy function which Osborne called α. Notice that in getting α by the method of differences in the fillings, not only is the energy correction for the heat capacity of the empty calorimeter eliminated but also other energy corrections which are the same as long as both liquid and vapor are in the calorimeter. These α experiments are essentially liquid heat capacity experiments.

Now consider another type of experiment, which may be called a vaporization experiment, for getting the enthalpy of the saturated vapor. Consider a calorimeter nearly filled with liquid and let energy be supplied to evaporate liquid to vapor, most of which is withdrawu through a throttle valve at a rate so controlled as to keep the temperature of evaporation constant. The theory shows that the heat added, ΔQ, divided by the mass withdrawn, ΔM, is equal to the latent heat L plus the correction, $L\dfrac{v}{v'-v}$. This correction is the energy necessary to vaporize water to fill the space no

longer filled with liquid. This gives the equation:

$$\frac{\Delta Q}{\Delta M} = L + L\frac{v}{v'-v} = \gamma.$$

The right-hand member of this equation is also a specific energy function, which Osborne called γ.

Now consider a third type of experiment where liquid instead of vapor is withdrawn as heat is added. Here liquid is evaporated to fill the space which is emptied of water. This gives the equation:

$$\frac{\Delta Q}{\Delta M} = L\frac{v}{v'-v} = \beta.$$

This is the same quantity that appears as a correction term in the preceding equations for the heat of the liquid and the heat of vaporization. This function he called β.

These three functions, which can be determined experimentally, may be used to calculate the more familiar functions

$$H = \alpha + \beta$$
$$L = \gamma - \beta = H' - H$$
$$H' = H + L = \alpha + \gamma.$$

So far these derivations use only the first law of thermodynamics. If the second law with the Clapeyron relation is used, the following equations result:

$$\beta = L\frac{v}{v'-v} = vT\frac{dp}{dT}$$

$$\gamma = L + L\frac{v}{v'-v} = L\frac{v'}{v'-v} = v'T\frac{dp}{dT}$$

where T is the absolute temperature and p the vapor pressure. These relations give a way of comparing the calorimetric data with the volumetric data such as has been obtained at the M.I.T., provided the vapor pressure slope and the absolute temperature are known.

For water the α is nearly a linear function of temperature. The β is very small at the freezing point but increases progressively until the slope is infinite at the critical point. The γ is everywhere greater than the β by the latent heat L. At the critical temperature when L becomes zero the β and γ curves meet.

Both β and γ can be measured with the same absolute accuracy; hence measured values of β can be subtracted from measured values of γ to get L without loss of accuracy. The Clapeyron relation in the equations above, however, provides a method of computing β with greater accuracy when β is small, provided v and dp/dT are known with a moderate accuracy.

For the measurements of these properties, a calorimeter is used for containing a sample of water while its thermal behavior is observed. The thermal behavior is determined by three principal quantities that must be measured, namely:

1. Mass subjected to process.
2. Energy added to system.
3. Change of state produced.

The measurement of mass is relatively simple because the samples are sealed in tight containers with valves, and never opened to the outside when accounting for mass. The measurement of energy is not so simple, because no way has yet been found to make calorimeters quite tight for heat. The measurement of the change of state involves the measurement of changes in temperature or pressure.

The first calorimeter (*11*) for this work was made of a copper-nickel alloy, and was 3 inches in diameter, 6 inches high, with rounded ends. This calorimeter was silver-plated on the inside, to provide protection against contamination of the water, and on the outside, to present a bright surface to make radiation small. Small tubes at the top and bottom served both as supports for the calorimeter and as ducts for fluids. The tube at the bottom contained a hollow shaft for driving a centrifugal pump in the calorimeter which circulated a sheet of water over the entire inside wall for distribution of heat. This pump also supplied a flowing film of water over a sheathed heater which was covered with silver gauze. Here the electric energy was added to the calorimeter. The casings for circulating water were made of pure silver, the pump was made of gold-silver and silver-palladium alloy, and the

pump bearings were made with osmium-iridium balls and races.

The calorimeter was supported inside of a larger copper-nickel shell, called an envelope, which also was silver-plated on the inside. The space between these shells was evacuated during the experiments to make negligible the heat exchange by gaseous conduction and convection. The envelope was mounted in a circulating bath of oil whose temperature was controlled to keep the envelope temperature very close to the calorimeter temperature.

The thermometric installation on this calorimeter and its successors was novel and characteristic of Osborne's experimental methods. Temperatures were measured and controlled with a combination of platinum resistance thermometers and thermoelements mounted on a thick copper reference block directly above the envelope. The temperature of the reference block was determined accurately with resistance thermometers. The small temperature differences between this reference block and vital parts of the apparatus were determined by differential thermoelements having reference junctions on the reference block and principal junctions distributed at chosen places on the surface of the calorimeter and its envelope. These elements were used in groups to determine the small difference between the integrated surface temperature of the calorimeter and the temperature of the reference block. The elements on the calorimeter were opposed to the elements on the envelope so that the envelope temperature could be controlled close to that of the calorimeter in order to avoid any considerable heat exchange. The indications of these differential thermoelements were observed and recorded every minute during experiments, so that proper account could be made of the residual heat exchange with the envelope.

The water used in these experiments was taken from laboratory stills and then redistilled in a special still, which removed all but about 0.1 percent of the dissolved gases. The water was then stored and weighed in silver containers sealed with diaphragm valves before it was introduced into the calorimeter. These diaphragm valves were made entirely of metal and had no stuffing boxes. The masses introduced into the calorimeter ranged from about 275 grams up to nearly 500 grams.

The electric power, added to the calorimeter heater, was taken from storage batteries and measured with a five dial potentiometer, which determined both the current to the calorimeter and the potential drop across the leads. The power was then multiplied by the time to give the electric energy input. The circulating pump supplied less than 0.1 watt of power, but calorimetric determinations showed this power to be somewhat uncertain, and so it may have been one of the greater limitations to accurate accounting of energy in this calorimeter. These energies, together with the net energy added to the calorimeter by conduction and radiation, integrated over the period of the experiments by means of the differential thermoelement readings, made up the total energy input.

The α or heat-capacity experiments were made by first measuring the temperature of the calorimeter with the thermometers and thermoelements when the envelope temperature was adjusted and the circulating pump running. Power input was then started by means of a switch, which was activated by a spring but released by the signals from a Riefler clock. At the end of a predetermined time (usually 10 minutes), when sufficient energy had been added to raise the temperature of the calorimeter and its contents by the desired amount (usually 10°), the power was switched off by the same switch. During this heating period the envelope temperature was kept near the calorimeter temperature so that the net heat transfer would be small. In general a few minutes after the end of the period of heating, a satisfactory temperature equilibrium had been attained so that this temperature could be determined and another experiment started. This process was continued with both large and small masses in the calorimeter until 8 to 18 experiments had been made in each 10° temperature interval in successive steps over the entire range from about 1° up to 270°C. These measurements furnished the data for formulating α as a function of temperature.

The γ experiments were performed at 8 nominal temperatures, from 100° up to 270°C. In these experiments the envelope bath was thermostated to keep the temperature constant. As power was supplied by the heater, vapor was withdrawn through a throttle valve continuously controlled by the operator to maintain a constant temperature on the surface of the calorimeter. The vapor was first condensed in one of the silver containers until proper temperature and flow conditions were attained. A series of temperature readings was then taken, and midway in this series the flow was shifted to another container by opening and closing valves operated by a spring and released by signals from the clock. The durations of these experiments varied from ten minutes to an hour, and sometimes as many as eight experiments were made successively on one day. The rates of flow were varied from about half a gram per minute to 2 grams per minute for the purpose of detecting any systematic variation in the derived γ such as might be caused by the withdrawal of liquid droplets along with the vapor.

The β experiments were performed in a manner somewhat similar to the γ experiments, except that liquid was throttled out of the bottom of the calorimeter. Since it was desirable to remove most of the available liquid contents in one experiment the flow and power input were started and stopped, instead of being continuous as in the γ experiments.

All known corrections were applied to these measurements, and then adjustments were made to reduce the results to even temperatures for ease in formulating. When the formulation was completed a table was made which gave values of the enthalpies H and H', the latent heat L, and the entropy S and S', of both the saturated liquid and saturated vapor at each integral 10°C. from 0° to 270°C. This was published (*11*) in 1930, and the engineers proceeded to incorporate these results in steam tables.

The engineers by this time were eager to have information about the properties of water and steam at still higher temperatures because, in striving for higher efficiency, turbines were being made to run at higher pressures. The experiments up to 270°C. had proved the great value of Osborne's method of calorimetry for attaining accurate values of the enthalpy of saturated liquid and saturated vapor but certain features of the first calorimeter were inadequate for measurements at higher temperatures and pressures. Considerable difficulty had been experienced in maintaining constant temperature control with the oil bath at 270°C. Furthermore, the copper-nickel calorimeter was not strong enough to withstand a fourfold increase in pressure at a 100° increase in temperature. In addition, it was not considered feasible to make a pump shaft stuffing box which would hold four times the pressure because the erosion of the shaft had already been excessive at the higher pressures. Again there was a strong suspicion that the pump power was not a single valued function of the pump speed and that uncertainties in its power input existed.

In the meantime metallurgists had been developing new stainless steels, and so it was decided to make a new calorimeter of a stainless steel made of a chromium-nickel-tungsten alloy, which had the property of low creep at high temperatures. This calorimeter (*12*) was 2½ inches in I.D. and 5½ inches high with hemispherical ends. The wall was only an eighth of an inch thick, yet it was strong enough to hold the critical pressure of water of over 218 atmospheres. It was machined out of a solid bar of steel that had been compressed axially in a hydraulic press so as to give extra strength to the calorimeter by circumferential work-hardening. This calorimeter, like the first, was supported by tubes at the top and bottom for introducing and withdrawing fluid. The heater in this calorimeter was small and was concentrated near the bottom so that the energy would cause bubbles of vapor to form and rise near the axis of the calorimeter and hence cause some stirring to accelerate the distribution of heat. Heat was distributed also by conduction in 30 flat plates of 0.5 mm silver, which were mounted radially from the axis to the shell to provide good thermal connection throughout the calorimeter.

It was decided not to provide for evacuat-

ing the space around this calorimeter, partly because it simplified construction when highest precision was not demanded and partly because the proportionate saving in heat leak was not so great at the higher temperatures where radiation predominates. The isothermal envelope around this calorimeter was a shell of pure silver 4 inches O.D. and a quarter of an inch thick, with quarter-inch silver plates in the ends. This in turn was surrounded with a 5-inch O.D. pure silver shell one-eighth inch thick with end plates. Silver was used because it is the best conductor of heat and because it also has the lowest emissivity for radiation. The function of the inner silver shell was to present a controlled isothermal surface to the calorimeter. The function of the outer shell was to withstand the brunt of the envelope heat supply and to maintain its average temperature near the calorimeter temperature, while losing heat to the room. The outer silver shell was insulated with an inch of air partitioned with two thin concentric aluminum radiation envelopes. This was all contained in a heavy brass casing of sufficient strength to hold the contents of the calorimeter in the event of a rupture while in service. A heater on the outer silver shell constantly supplied heat to keep its temperature up to the calorimeter temperature. A heater on the inner shell was used only when the temperature was being raised such as in the α experiments.

The reference block in this apparatus was located above the calorimeter inside the heavy silver shell and was made of two pieces of silver ¼ by 1½ by 2½ inches held together horizontally and having a vertical hole in the center one-half inch in diameter for the vapor outlet tube. This block held two resistance thermometers and 31 thermoelement reference junctions. More junctions were used on this calorimeter than on the first calorimeter to compensate partly for the lack of stirring in the calorimeter and also for the lack of vacuum insulation around it.

It was decided to use the calorimeter first to measure the vapor pressure of water over the range from 100°C. up to the critical temperature. This decision was fortunate because the results of these measurements inspired Professor Keyes (*13*), at the Massachusetts Institute of Technology, to remeasure the vapor pressure of water. These two determinations were then in satisfactory accord with the similar determination just previously made in England by Prof. A. C. Egerton and G. S. Callendar (*14*), the latter being the son of the late Prof. Hugh Callendar, mentioned in connection with Barnes.

The principal accessories to the calorimeter that were needed for the measurements of vapor pressure were a pressure capsule and a precision pressure gauge. The pressure capsule was required to transmit the pressure to the outside of the calorimeter without loss or pollution of its fluid contents. It was made of a pair of stainless steel disks, each 2 inches in diameter and over one-half inch thick, clamping a 0.0025-inch silver diaphragm at the edge. The pair of disks were hollowed out to conform to the shape of the deflected diaphragm so that it would be supported without excessive strain when large pressure differences were applied, yet left free to balance small pressure differences. The total volume displacement of the diaphragm between supports was only 0.04 cm.³ Water extended from the outer side of the diaphragm to a water-air meniscus in a glass capillary indicator. A motion of the meniscus of 0.6 mm indicated a change of pressure of 0.001 atmosphere when the diaphragm was near the center of the cell. The pressure was transmitted by the air to an air-oil meniscus in another capillary and from that through the oil to the pressure gage.

The pressure gage was one of the rotating dead-weight precision piston gages constructed at the N.B.S. and described by Meyers and Jessup (*15*). The piston of this gage could be loaded with weights to balance the pressure to a precision of about 0.001 atmosphere. The oil not only supported the rotating piston but lubricated it as well.

The preparation for vapor-pressure determinations consisted in maintaining a constant temperature in the partly filled calorimeter for a sufficiently long time to be certain that the wall temperature of the calorimeter represented the temperature of

the free liquid-vapor surface. The pressure in the piston gage was then brought into balance with the vapor pressure in the calorimeter and simultaneous determinations were made of the load on the piston, the resistance of the platinum thermometers in the reference block, and the e.m.f. of the differential thermoelements leading from the reference block to the calorimeter.

At temperatures up to 350°C. the measurements were relatively simple and definite. Above 350°C. the steady state was reached much more slowly and temperature gradients were larger over the calorimeter shell. Near the critical temperature, where the specific volume of the saturated water changes most rapidly, it was necessary to start measurements with the calorimeter full of water and then continue measurements at successively reduced fillings so that the liquid would be at the proper level for some filling.

In 1934 Osborne and Meyers (*16*) published "A Formula and Tables for the Pressure of Saturated Water Vapor in the Range 0 to 374°C." For the upper range of temperature, this formula was based on the three recent researches mentioned above and in the range below 100°C. upon the classic data which were obtained at the Physikalisch-Technische Reichsanstalt (*17*) before 1909. The form of equation was one that, in the judgment of the authors, closely represented the data, and was suitable for numerical calculation of the pressure and its derivative. This formula was used to compute tables of both the vapor pressure and its slope at intervals of 1°C. and 1°F. over the range. These intervals are small enough so that linear interpolations suffice to determine either the pressure or its derivative at nonintegral temperatures.

When the measurements of the vapor pressure had been completed, a few extra accessory parts were installed in order to make the calorimetric measurements. Among these accessories (*18*) were two sensitive throttle valves, one for throttling the liquid, and the other for throttling the vapor. These valves were of the diaphragm type, which had no stuffing boxes. The motion necessary to adjust the throttling was produced by a screw, acting on a long lever supported on knife-edge bearings. Backlash was eliminated by a spring, acting on another similar lever which opposed the thrust of the screw. When the levers had been adjusted to give approximately the correct flow, it was thereafter controlled by varying the tension of the springs to the backlash levers. This control proved to be very delicate and positive. It was adequate for the control of temperature and was free from the annoyances which had been caused by the pivoted bearings of the throttle valves used with the first calorimeter.

The control of the temperature of vaporization was accomplished by controlling the vapor pressure at the free surface where evaporation was taking place. This method of control of the temperature of vaporization is nearest to the ideal because there is little question that the temperature of the free surface responds almost instantaneously to changes in the pressure of the vapor above the liquid. Part of the same pressure line that had been used for the vapor pressure measurements was used for this control, but in place of the piston gauge there was an air reservoir, which was kept immersed in an ice bath to maintain a constant reference pressure. The pressure in this reservoir was first adjusted to balance the pressure in the calorimeter when equilibrium existed, then after the power was switched on, the flow of fluid out of the calorimeter was continuously adjusted to maintain this same pressure balance and hence the same temperature at the evaporating surface.

The β experiments were performed by starting and stopping the flow of liquid in the same manner as was done in experiments with the first calorimeter. The γ experiments were performed by two methods, one by switching the flow of vapor from one receiver to another as with the first calorimeter, and the other by the start and stop method used for the β experiments. This latter method of performing the γ experiments was made more reliable by the temperature control of the free surface just described. The resulting values of γ when compared with those obtained by the first method and with those obtained with the first calorimeter did not show any sig-

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nificant systematic differences resulting either from the method or the apparatus.

As before, the α function was derived from repeated measurements with both high and low fillings. These covered each 10° interval from 100° to 370°C. with the addition of numerous measurements over 50° intervals from 100° to 350°C.

The β function was derived from measurements at temperatures from 200°C. up but at more closely spaced temperatures toward the critical temperature where the slope of the β function changes most rapidly. The measured values of β were compared with values calculated from the M.I.T. (*19*) pressure-volume-temperature measurements by means of the Clapeyron relation. At temperatures below 220°C. the derived β was undoubtedly more trustworthy than the measured β. Between 220° and 330°C. the precision of the measured β is comparable with that of the derived value but above 330°C. the measured values of β are more reliable and therefore were used in the formulation. Conversely, this means that the values of the specific volume of the liquid above 330°C. are more reliable when derived from the vaporization experiments than when derived from the pressure-volume-temperature measurements.

Measurements were also made on the γ function at temperatures from 100°C. up to and including 374°C. As the critical temperature (N.B.S. estimate 374.15°C.) is approached, the specific volume of both the liquid and the vapor approaches equality, and the liquid and vapor tend to mix owing to such causes as residual temperature gradients and thermal agitation. It is to be expected that at some temperature near the critical the mixing of phases will be so great that liquid will be withdrawn along with vapor in the γ experiments and vapor with the liquid in β experiments. Provisions, such as baffles at the upper and lower ends of the calorimeter, were made to avoid this as far as possible. In the experimental program, the rates of withdrawal were varied in order to detect mixing. It appears, however, from the consistency of the results, that there was no positive evidence of mixing until the fluids were within 1° of the critical temperature. At 373.5°C. both the β and the γ experiments indicated indeterminate results, whereas, at 373°C. and lower, there was little, if any, evidence of it.

In the specific volume determinations made at M.I.T., however, isometric lines must be extrapolated to the saturation line from the compressed liquid or the superheated vapor. As the critical temperature is approached, the curvature of these isometric lines increases toward the saturation line and the extrapolation becomes more uncertain. For these reasons, it appears that the thermal properties of saturated water and water vapor can be most reliably measured with a saturation calorimeter, as the critical temperature is approached. Very close to the critical temperature, even these measurements become indeterminate.

These measurements concluded the determination of the properties of saturated water and water vapor at high temperature but left the enthalpy of the saturated vapor below 100°C. almost untouched. In the meantime there had arisen a request for increased accuracy in the determination of the properties of saturated liquid below 100°C. where water is most frequently used for the exchange of energy in certain types of calorimetric experiments. It was therefore decided to make a third apparatus (*20*) to measure the enthalpy of saturated liquid to an accuracy of 1 part in 5,000 and also to use this apparatus to complete the measurements of the heat of vaporization of water over the entire range down to the freezing point.

Since 100°C. was set as the upper limit of temperature required, it was unnecessary for the calorimeter to withstand any pressure difference of more than one atmosphere and hence the calorimeter could be larger and of much lighter construction. This calorimeter was made of pure copper, 0.022 inch thick, spun into two hemispherical shells 5 inches in diameter and soldered together with a narrow cylindrical copper band at the equatorial zone. The surfaces inside and out were gold-plated and the outside surfaces polished to make the emissivity low. A circulating pump consisting of two screw propellers was provided to agitate and circulate the water, and guide vanes were provided to direct the flow. A

sheathed heater in a flat horizontal coil provided the power for the experiments. As before, the calorimeter was supported by tubes at the poles. The lower tube was small and contained the pump shaft while the upper one was large to conduct large volumes of vapor out of the calorimeter in those γ experiments where the specific volume was large.

The envelope was a double-walled vapor bath, entirely surrounding the calorimeter. This bath always contained a small quantity of liquid water so that saturated vapor bathed the entire inner wall. Heat applied to the outside wall at the level of the water in this bath caused vapor to be formed which had access to all parts of the bath without any appreciable drop in pressure. Any portion of the entire inside surface, which chanced to be at a temperature lower than that corresponding to the vapor pressure, immediately received the latent heat from condensation on that portion. Provision was also made to keep the inner wall bathed with a film of liquid which could evaporate to cause cooling wherever necessary. The inside of the inner wall of this envelope was gold-plated and polished to make the emissivity low where it faced the calorimeter. The space between the calorimeter and the envelope was evacuated when thermal insulation was needed, but it was filled with helium when thermal connection to the envelope was desired, such as when refrigeration was needed to cool the calorimeter and its contents before starting a day's run near 0°C. At such times a flow of ice water in a condenser at the top of the envelope vapor space caused condensed water to run down over the inner wall where it evaporated and thus cooled the wall.

The copper reference block for this calorimeter was inclosed in a cylindrical extension of the double-walled envelope enclosure so that its temperature would be the same as that of the envelope around the calorimeter. This copper reference block had axial sockets for the usual laboratory type of resistance thermometers and had 22 thermoelements attached.

Since higher accuracy was sought, special attention was directed both to the details of the design and to the technique of measurement. The greater difference in the masses of water in the high and low fillings was one factor toward this end. Other factors included the measurement of power and temperature. The potentiometer calibration was checked at least twice a day against saturated standard cells kept in a special temperature-controlled box. Many calorimetric measurements of the pump power showed some irregularities, as before, but since the total pump power was less than 0.005 watt, these irregularities were of little consequence. The heat leak corrections due to temperature differences between the calorimeter and the envelope were taken into account although they seldom made an effect of as much as 1 part in 50,000.

No β experiments were made with this calorimeter because β is small in this temperature range and it could be computed more accurately than it could be observed. The γ experiments were made with a throttle very similar to the one in the second calorimeter, but larger. The steam throttled through this valve was collected in glass reservoirs through tubes and stopcocks, which were nowhere less than 1 cm in diameter. When in use the bottom of these receivers was immersed in liquid air which maintained the vapor pressure at a negligibly low value. Vaporization experiments were made at temperatures as low as 0.13°C. where the specific volume of the vapor is over 200,000 cm³ per gram.

The results (*20*) obtained with this calorimeter were expressed in terms of enthalpy in the same manner that the earlier results had been, but in this temperature range there is also another important property, namely, the specific heat at constant pressure denoted by the symbol C_p. To derive this quantity the values from the α experiments were reduced to weighted means of $\Delta\alpha/\Delta T$ at the midtemperatures of all the intervals of the range. These were then reduced to $\frac{\Delta H_{\text{sat}}}{\Delta T}$ by means of the β function, then to $\frac{\Delta H_{1\text{ atm}}}{\Delta T}$, and finally to $\frac{dH_{1\text{ atm}}}{dT}$ which is the C_p. The weighted mean values

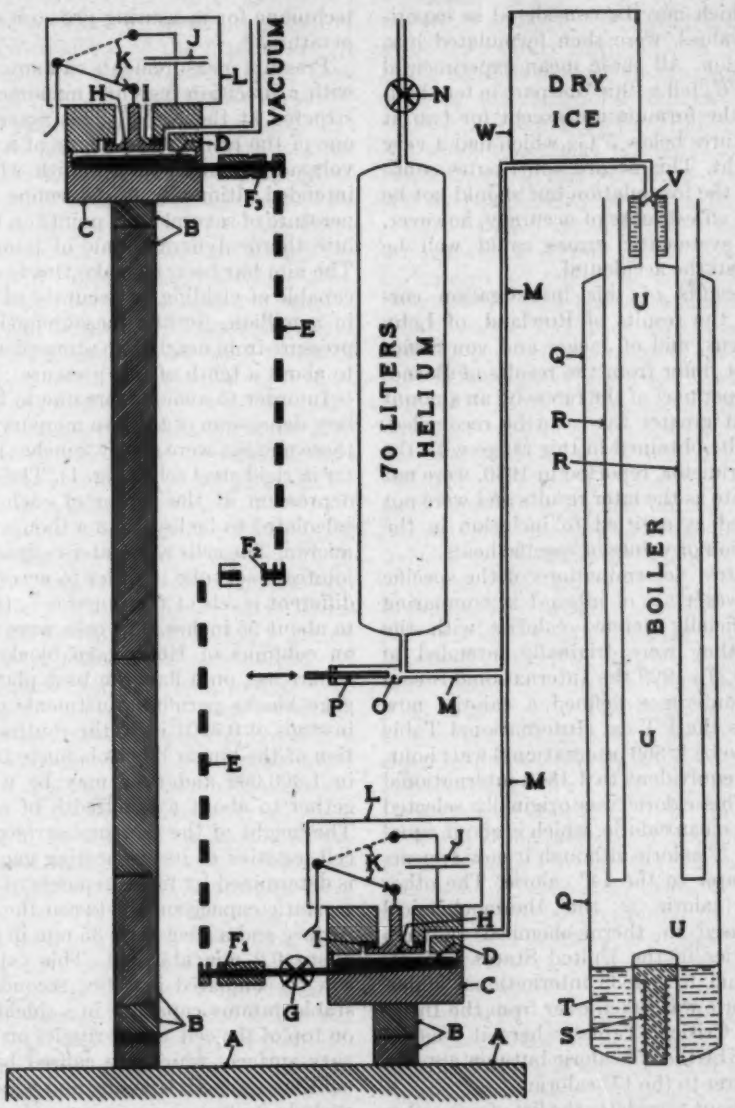

FIG. 1.—Schematic diagram of precision manometer, with boiler for vapor pressure measurements: A, Base plate; B, column of Hoke gage blocks 1 inch square; C, mercury cell; D, mercury meniscus, 73 mm in diameter; E, arm of jointed tube ¼ inch I.D. to connect mercury cells, dotted to indicate that it is back of plane of cells; F_1, F_2, F_3, tube joints, shoulder, elbow, and wrist; G, valve to shut off the mercury connection between cells; H, capacitance plate 35 mm in diameter, 0.2 mm above mercury; I, electric insulation, gas tight; J, fixed capacitance, equal to plate-mercury capacitance; K, pneumatic switch, connecting either to fixed capacitor or to plate-mercury capacitor; L, electrostatic shield; M, helium line; N, helium supply valve; O, 7-milliliter volume for pressure adjustment; P, piston for micrometer adjustment of pressure; Q, thermometer boiler; R, thermometer well; S, heater for boiling water; T, liquid water; U, water vapor; V, vapor condenser with cold water; W, dry-ice cell for keeping helium line dry.

of C_p, which may be considered as experimental values, were then formulated into an equation. All these mean experimental values of C_p fell within one part in ten thousand of the formulation except for two at temperatures below 5°C., which had a very low weight. This accord contributes confidence to the formulation but should not be taken as an estimate of accuracy, however, because systematic errors could well be larger than the accidental.

The results of this investigation corroborate the results of Rowland, of Laby and Hercus, and of Jaeger and von Steinwehr, but differ from the results of Barnes in the upper part of the range by an amount somewhat greater than can be reconciled. The results obtained in this range with the first calorimeter, reported in 1930, were not so accurate as the later results and were not considered as entitled to inclusion in the formulation of values of specific heats.

The latest determinations of the specific heat of water are of interest in comparing two artificially defined calories with the calories they were originally intended to represent. In 1929 the International Steam Table Conference defined a calorie, now known as the I T cal (International Table calorie) to be 1/860 international watt hour, which is equivalent to 4.1860 international joules. This calorie was originally selected to be the mean calorie, which is about equal to the 11.5° calorie although it now appears to be nearer to the 14° calorie. The other artificial calorie is the thermochemical calorie used in thermochemical research laboratories in the United States and defined equal to 4.1833 international joules. This calorie was taken over from the International Critical Tables where it was intended to be the 15° calorie but now appears to be nearer to the 17° calorie.

This about completes the list of researches on water under the leadership of N. S. Osborne. It leaves one gap, however, which he had hoped to see filled, namely, the measurement of the vapor pressure of water at temperatures below 100°C. The Reichsanstalt values (*17*) are still widely used but it is believed that more accurate values can be obtained with the present advances in the technique for measuring pressure and temperature.

Pressure measurements can now be made with a precision mercury manometer, constructed at the N.B.S. This manometer is one of the principal elements of a constant volume gas thermometer with which it is intended ultimately to determine the temperature of several fixed points on the absolute thermodynamic scale of temperature. The aim has been to make this manometer capable of yielding an accuracy of one part in a million, for the measurement of any pressure from nearly two atmospheres down to about a tenth of this pressure.

In order to avoid errors due to the capillary depression of the two mercury menisci, these menisci were nearly 3 inches in diameter in rigid steel cells (Fig. 1). The capillary depression at the center of each cell was calculated to be less than a thousandth of a micron. The cells were inter-connected by a jointed steel tube in order to accommodate different levels of the upper cell, from 0 up to about 55 inches. The cells were mounted on columns of Hoke gage blocks, 1 inch square, set on a flat iron base plate. These gage blocks permit adjustments of height in steps of 0.0001 inch, the routine calibration of the longer blocks is made to 2 parts in 1,000,000 and they may be wrung together to about a hundredth of a micron. The height of the mercury surface in each cell, relative to its supporting gage blocks, is determined by measurements of the electrostatic capacitance between the mercury surface and a steel plate 35 mm in diameter about 0.2 mm above it. This capacitance can be compared in a few seconds with a stable dummy capacitor in a shielded space on top of the cell. Small ripples on the mercury surface, which are caused by almost continuous earth tremors, and which would exclude its use as one mirror of an optical interferometer, do not affect the capacitance measurements. The capacitance is measured with a beat-frequency oscillator which is sensitive to a change in the height of the mercury surface of about a hundredth of a micron.

It was intended to give this manometer its first workout in making measurements of

the vapor pressure of water at pressures within the capacity of the manometer. A few preliminary measurements have been made at 80°, 60°, 50°, and 25°C. with active boiling of water in a specially designed thermometer boiler. At the top of this boiler there was a condenser where the stream of water vapor condensed and transmitted its pressure to helium extending to the lower cell of the mercury manometer. It soon became evident, however, that the vapor pressure of water could be measured with a much greater accuracy with this manometer than the corresponding accuracy to which temperature could be measured with thermometers calibrated by routine methods. For this reason further measurements were deferred until a few more refinements could be put on the calibration of the platinum resistance thermometers.

This apparatus is suitable for providing and maintaining a pressure very precisely at one atmosphere for calibration of thermometers at 100°C. Pressures can be maintained constant within one part in a million for periods of an hour or more at will. At 100°C. this corresponds to a temperature constancy of much better than 0.0001°C. The determination of the steam point in a closed system connected to this manometer is as much superior to determinations in apparatus open to the atmosphere, as determinations of specific and latent heat of water in closed calorimeters were superior to measurements where water samples were caught in open vessels for weighing.

It had been recognized for a long time that individual steam-point determinations in open boilers are subject to uncertainties of a few thousandths of a degree, but it had not been fully appreciated that ice-point determinations, without special technique, are also subject to uncertainties of one or more thousandths of a degree. The ice point, or 0°C., is defined (*21*) as the "Temperature of equilibrium between ice and air-saturated water at normal atmospheric pressure." When this definition was set up, the ice bath, made of finely divided pure ice and distilled water exposed to the atmosphere, was assumed to be sufficiently accurate to fix this temperature to 0.001°C. When an accuracy of 0.0001°C. was desired there was some uncertainty in the precise realization of the conditions of the definition as will be seen. It was recognized that the temperature of pure water at the triple point was the simpler to define precisely, but it was considered that the apparatus for using it was too complicated for routine testing.

Since water expands on freezing, the temperature of equilibrium of ice and water is lowered by pressure. Using what are believed to be the best data now available, this lowering has been computed to be 0.00747°C. when the water is subjected to one atmosphere pressure. Foreign substances in solution also lower the freezing temperature. There are uncertainties about the exact values for the solubilities of the constituents of air in water but computations show that normal outdoor air containing 0.03 percent of CO_2 lowers the freezing temperature by about 0.00244°C. when the ice bath is at one atmosphere pressure. The pressure and the dissolved air together lower the freezing temperature by about 0.00991°C., which means that the triple point is nearly 0.0100° above 0°C. This difference of temperature has been determined experimentally by four reliable experimenters, viz., H. Moser (*22*) at the Reichsanstalt, W. P. White (*23*) at the Geophysical Laboratory, J. L. Thomas (*24*) at the National Bureau of Standards, and J. A. Beattie (*25*) at the Massachusetts Institute of Technology. All four reported the triple-point temperature to be 0.0098°C. above the ice point. This temperature difference is less than the theoretical, but it could be accounted for either by the presence of foreign matter in solution in their triple-point cells or because the water in their ice baths was not fully saturated with air at the ice-water interfaces nearest their temperature measuring instruments. It is well known that the saturation concentration of air in ice is much less than in water. For this reason water from newly melted ice will not be fully saturated with air until the necessary amount of air has had time to diffuse into it all the way from the surface of the ice bath. Since temperature is determined by the conditions at the ice-water

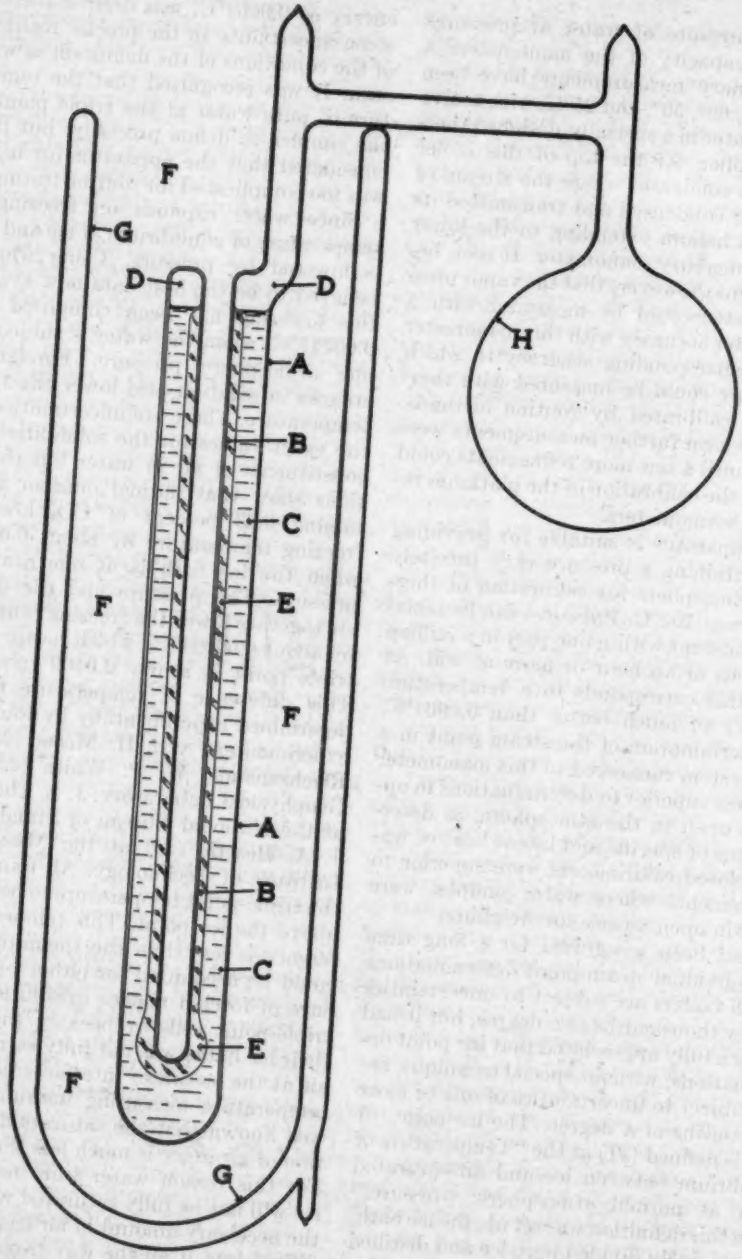

FIG. 2.—Triple-point apparatus: A, triple-point cell; B, thermometer well; C, liquid water; D, water vapor; E, ice mantle; F, ice bath; G, vacuum vessel; H, flask for redistillation.

interfaces, it follows that complete saturation of air in water under normal atmospheric pressure must extend to the interfaces nearest the thermometer to realize the defined temperature of 0°C. in water that is pure otherwise. It becomes a bit delicate, therefore, to get the water completely polluted with air at the ice surface but with nothing else. White and Beattie provided means for washing the ice in the ice baths with successive changes of distilled water saturated with air at 0°C. Melting ice, as suggested in the publication "The International Temperature Scale" (*21*), almost certainly will prevent complete saturation of the water with air.

After these considerations a triple-point apparatus for precise determinations of temperature did not seem as formidable to make and use as a precision ice-point apparatus. Several triple-point cells (Fig. 2) were prepared and a suitable technique was developed to use them effectively. When in use these cells were completely immersed in an ice bath. The cells were of Pyrex glass about 2 inches in diameter and about 16 inches long with one-half-inch reentrant coaxial wells for the thermometers. Each cell also had a tube extending out through the top of the ice bath to a spherical 1-liter flask at the side. Each cell was filled nearly to the top with ordinary distilled water, which had been air-freed, repurified, and then distilled into the cell before sealing off. When the water was sealed in the apparatus, any non-volatile contamination such as dissolved glass could be eliminated at will by pouring the liquid into the flask and allowing it to redistill quietly into the cell by keeping the cell in an ice bath for about a day.

The cells were prepared for use by freezing a mantle of ice on the thermometer well with solid CO_2, commercially known as dry ice. Dry ice was dropped into a little ethanol in a glass tube which was like a long test tube, fitting freely into the well. The space between the tube and the well was filled with ethanol and the tube agitated up and down in order to cause the ice mantle to form uniformly on the outside of the well. Agitation was continued until the mantle of ice was from 3 to 6 mm thick, and then the tube was let down for a while to thicken the mantle at the bottom. During the process of freezing, impurities tend to be excluded from the ice and therefore concentrate in the water at the surface of the ice where they exaggerate the lowering of the freezing temperature until after these impurities have had time to diffuse away from the surface throughout the water in the cell. Most of this lowering can be avoided by the simple expedient, suggested by W. P. White (*23*), of heating the well just enough to melt ice to give a thin film of water next to the well, which is where the ice first was frozen and where the purest ice exists. This surface then surrounds the thermometer well and provides a simple means of almost completely enclosing the thermometer in a surface which is isothermal except for the small temperature gradient due to the increase of pressure with increasing depth of immersion. These cells take only a few minutes to prepare for use and can be kept for many hours in an ice bath. They are probably reliable to about ten times the precision of the usual ice bath and when available they do not require a much longer time to prepare for measurements.

With the triple-point cells available, there arose the question of the precise temperature of the triple point, relative to the defined ice point. This meant that the defined ice-point temperature would have to be realized to compare it with the triple-point temperature. To do this, an ice-point cell (Fig. 3) was made which in principle resembled the triple-point cell but also had provisions for saturating the water surrounding the ice mantle with air. Extra care was taken during the distillation and purification of the water introduced into this cell so that it could be kept pure. Several days were required to prepare the water sample which was then sealed into the cell so that it could be used first like a triple-point cell.

To prepare for the determination of the triple-point temperature, ice was frozen on the thermometer well of the ice-point cell and also on the walls of three triple-point cells. Triple-point temperatures were ob-

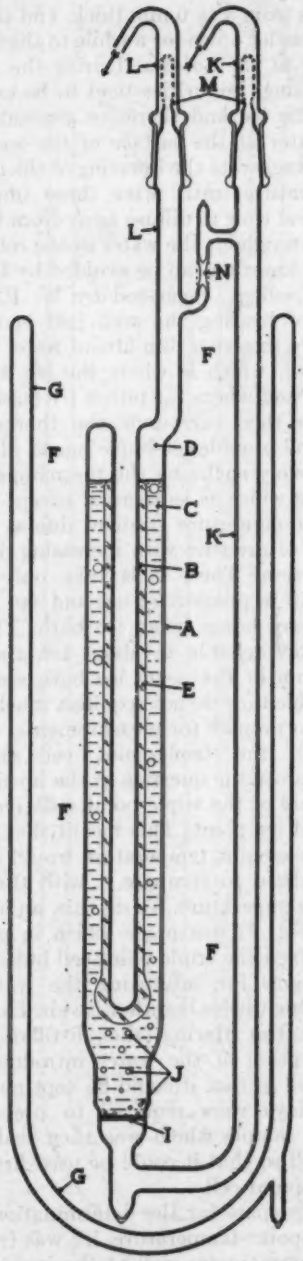

FIG. 3.—Ice-point apparatus: A, ice-point cell; B, thermometer well; C, liquid water; D, water vapor and air; E, ice mantle; F, ice bath; G, vacuum vessel; I, fritted disk; J, air bubbles; K, air inlet tube; L, air outlet tube; M, tip broken to admit air; N, bypass, sealed after air admission.

served first in triple-point cells and then in the ice-point cell using the exterior surface of its ice mantle. When this had been done the ends of the two tubes that led to and from the cell were cut off. This admitted the pressure of the atmosphere to the liquid surface in the cell and lowered the temperature. The temperature was then observed as soon as possible, and temperature observations continued for some time, so that the temperature could be extrapolated back to the time of admitting the pressure. Since air could not diffuse immediately from the top surface of the water down to the ice surface surrounding the thermometer, the extrapolated temperature difference was assumed to be caused by the pressure of the atmosphere.

Air, free of CO_2, was then forced into the cell through a fritted disk beneath the thermometer well, thus causing small bubbles to rise past the ice mantle and to saturate the surrounding water with air. This process was continued for a long time until temperature equilibrium was established. This temperature was assumed to be the temperature of equilibrium between ice and air-saturated water free from CO_2 at standard atmospheric pressure. The thermometer was then put into the triple-point cells again to check the thermometer and bridge for any drift during the day.

With the observed temperature, corrected to the basis of standard atmospheric pressure and 0.03 percent of CO_2 in the air, the temperature determined for the triple point of water in this one experiment was 0.00997°C. (*26*), with no claim made for the reliability of the last decimal figure. Only one experiment was performed, however, because immediately afterward, in 1942, this research had to be set aside for work of higher priority.

The result of this experiment indicates that the temperature of the triple point of water is near enough to 0.0100°C. for most purposes. It is consequently suggested that a future precise definition of the centigrade scale of temperature might define 0°C. as being 0.0100° below the triple point of water, instead of refining the present definition to include a specification for the precise composition of air. Such a change would make no significant difference in the present

temperature scale, but would make the definition simpler, more precise, and easier to realize when the highest precision is demanded. Moser (*22*), in 1928, recommended "the triple point of water as a fixed point of the temperature scale" and the experiments, described here, strengthen this recommendation.

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ARCHEOLOGY.—*The significance of the fiber-tempered pottery of the St. Johns area in Florida.*[1] JAMES B. GRIFFIN, Ceramic Repository for the Eastern United States, Ann Arbor, Mich.

Any discussion of fiber-tempered ware in the Southeast and more particularly in Florida must begin with the observations of Jeffries Wyman, who investigated the area in 1860, and again in 1867, and whose monograph on fresh-water shell mounds of the St. Johns, published in 1875, is still a significant contribution. He recognized that the pottery from the St. Johns shell heaps had little similarity to other Florida pottery and that cord-marked pottery did not often occur there while it did occur in the marine shell heaps near St. Augustine and along the Atlantic coast to the south. He observed that the check stamp was fairly common at the coast and river sites. Part of the distinctiveness of the St. Johns pottery was the ware tempered with fiber. Wyman says (1875, pp. 55–56)[2]:

> In several localities, as will be seen by the table, the natives added to the clay vegetable fibre derived from the palmetto tree. This appears to have been charred in the burning, thus making the vessel quite porous, each fibre leaving in its place, or around it as it shrunk from the heat, a small canal. In finishing the vessel, however, after it had been formed of fibre and clay, the surface within and without were covered with a thin layer or "skimming" of clay alone, thus counteracting in a measure the porousness resulting from the burning of the fibre. The only places at which this use of vegetable fibre was noticed were Old Town, Old Enterprise, Watson's Landing, as given in the table, and at Silver Spring on Lake George, and Palatka. This may, perhaps, be explained by the fact that the different communities had their own makers, each adopting a more or less peculiar style.

Wyman interpreted the absence of pottery from some of the mounds as evidence that they were earlier than the shell heaps that had pottery. This viewpoint was upheld by Moore as a result of his excavations along the St. Johns, and he added the observation that in some of the mounds pottery was found on the surface and part of the way toward a nonpottery basal layer. Holmes (1894) described the pottery from Moore's (1892–1894) early excavations and called one of his ceramic divisions "Midden Ware." He subdivided the midden ware into two groups. "One variety is characterized by a rather fine-grained paste preserving the warm gray colors of the baked clay. The surfaces are finished with a rubbing tool and are plain or have been rather carelessly embellished with patterns of incised straight and curved lines." The other subunit of the midden ware was fiber-tempered. At the time of my earlier studies on southeastern fiber-tempered ware, I had not seen examples from the St. Johns sites, and this has now been happily remedied.

While preparing a paper which interprets the cultural history of the eastern United States area, it appeared likely that the style and design of this pottery formed one of the component elements of the Tchefuncte ceramic complex of Louisiana and was hence at least as old as and probably older than the pottery from that aspect (Griffin, n.d.). At that time (1941) I compared the design to Alexander Incised of the early sand-tempered Alexander Series in the Southeast and after examining Wyman's collections in the Peabody Museum in Cambridge and Moore's collections in the Heye Museum in December 1941, I referred to the rectilinear design on fiber-tempered pottery as resembling Alexander Incised.

In March 1942 A. T. Anderson, of Melbourne, Fla., came to the Ceramic Repository for the Eastern United States at Ann Arbor and brought with him photographs of excavations and specimens from a site on his land, which is located almost due west of Melbourne on the St. Johns. From Anderson's account of the excavation it was evident that he had uncovered a significant

[1] This paper was read before the annual meeting of the Society for American Archaeology in Washington, D. C., in May 1944. The site at South Indian Fields was called to the attention of Dr. Irving Rouse, of the Peabody Museum of Yale University, who directed a field party which partially excavated the site in July and August 1944. A series of papers on these excavations and related Florida problems will be published by Yale University in the near future. Received March 5, 1945.

[2] See Literature Cited at end of paper.

site and that the lowest pottery bearing horizon was related to the incised fiber-tempered ware recovered by Wyman and Moore. The following description of Orange Incised and Orange Plain is based on Anderson's collection, on the earlier published reports and my examination of material in Cambridge, New York, and Washington.[3]

TYPE NAME: Orange Incised.

PASTE:

Method of manufacture: No evidence.

Temper: Fiber-tempered. Various proportions and sizes of a vegetal fiber almost entirely disintegrated in firing, presenting a vesicular appearance. There is no other nonplastic material visible in the clay.

Texture: Honey-combed.

Hardness: At least three-fourths of the sherds can be scratched by gypsum, while the others are 2–2.5.

Color: The exterior surfaces vary from a light cream to a dark gray. The surface color penetrates but a short distance (1 to 2 mm) and the core is very dark gray to black.

SURFACE FINISH: Both exterior and interior surfaces are fairly well smoothed. On some specimens this is sufficient to have formed a film over the fiber strands. On the majority of sherds the fiber tracks are visible on the outer or inner surface.

DECORATION:

Technique: Incising and punctating. The incising varies from lines made with a fine sharp point which are narrow (less than 2 mm) and medium deep, to medium wide (2–4 mm) and medium deep to deep incisions made with a rounded point. There is considerable variation in the skill of execution. The punctates are small shallow circular indentations or ovoid-shaped gashes.

Design: The designs are all rectilinear and are placed on the lip and outer rim or side wall of the vessel. The following patterns can be recognized.

1. Parallel vertical lines extending from the lip to the base of the wall.
2. Parallel horizontal lines extending from the lip to the vessel base.
3. Parallel left or right oblique lines extending from the lip to the basal angle.
4. Left and right oblique cross-hatched lines extending from the lip to the basal angle.
5. Large triangular areas with oblique hatching.
6. Groups of four or more oblique lines separated by a parallel plain band.
7. Groups of lines forming chevrons or inverted chevrons separated by a plain area.
8. A series of nested squares.
9. Nested squares or diamonds with vertical oblique or horizontal intersecting lines running through the corners of the squares or diamonds.
10. Hatched oblique bands outlined by incised lines.
11. Hatched areas set off from plain bands by incised lines.
12. Horizontally hatched triangles with adjoining inverted triangle plain.
13. Circular punctates or ovoid gashes paralleling or at right angles to incised lines.
14. Groups of oblique lines or chevrons on lip surface sometimes bordered by punctates.
15. The use of horizontal lines along the upper rim to delimit the decorated zone. This is used particularly with patterns 8 to 11 inclusive.

FORM:

Rim: Vertical, to slightly insloping in the upper segment of some specimens. There is no differentiation between a rim fragment and a side wall specimen.

Lip: Narrowed and rounded and without decoration, or very wide and decorated with incised lines and punctates. There is a tendency for the first 6 decorative patterns to occur on rims with narrowed lips and for patterns 8 to 11 to have wide, decorated lips. The flat lip may be horizontal or slope toward the interior.

Body: Rather shallow rimmed bowls or pans. Height from 7 to at least 15 cm. with the diameter varying from 20 cm. to vessels which were much larger.

Base: Flat. Some sherds presumed to be basal fragments have incised decorations of pattern 13 on their interior surfaces.

[3] The Department of Anthropology of the United States National Museum has kindly allowed me to reproduce a series of sherds from the Tick Island shell mound.

Thickness: Considerable variation from vessel to vessel. Narrow lips are 6 to 8 mm; the wide lip from 1.5 to 2.7 cm. Side walls from 8 mm to 1.8 cm and basal section 8 mm to 15 cm. The basal section often the thinnest part of the vessel.

Appendages: None. Examples of crack lacing holes.

USUAL RANGE OF TYPE: In the St. Johns drainage from South Indian Field north at the following sites of Wyman and Moore: Mulberry, Orange Mound, Huntingtons, Watson's Landing, Black Hammock, Enterprise, Mound in Woods above Blue Springs, Old Town, Mound below Lake Dexter, Tick Island, Silver Spring, Murphys Island, Palatka. To the west specimens were obtained in Ocala National Forest by Marshall Newman.

CHRONOLOGICAL POSITION OF TYPE IN RANGE: The earliest pottery found along the St. Johns. Is not found at all in some deep shell middens, on top layers of others and on bottom of still other shell middens which have later pottery types toward the top.

The plain sherds which are quite similar to the incised specimens can be called Orange Plain and differ in a few particulars from the incised specimens. The surfaces are usually not so well smoothed and the pieces seem somewhat less well made. Both the narrowed lip and the wide flat lip are found and some of the latter have incised decorations on them. There is thus no reason to believe that the plain specimens are significantly older or that a similar succession of plain to decorated is found either at South Indian Field or farther north in the St. Johns drainage as has been reported from the Bilbo site.

According to Anderson there also occurred in the lowest pottery zones an entirely different ware, which is an early form of the dominant temperless pottery along the St. Johns, and to this might be attached the appropriate name of St. Johns ware. A number of types can be recognized. One of these is incised (Fig. 1, S and T) and gives every indication of having developed or evolved from the earlier Orange Incised. On it there is a strong use of the horizontal line just below the lip on the outer rim forming an upper border for the incised pattern. The designs include some obvious carry-overs, but they are not so varied as on the fiber-tempered ware. Another type is a large check stamp, which is on thick coarse appearing sherds. Plain sherds are, of course, found and can be considered St. Johns Plain. A number of interesting traits are present on some of these dominantly plain sherds. One specimen has heavy scoring marks on the interior surface. Five specimens have fabric or mat impressions on the outer surface of flat circular bases (Fig. 1, U). The St. Johns ware forms a minority group in the earliest or third level at the South Indian Field site.

In Anderson's second level St. Johns Plain becomes the dominant ware with a continuation of the incised type and a few sherds of the check stamp. A newcomer is a plain sandy or gritty ware, which is probably related to the Glades Gritty Ware of Stirling and Goggin (1940). One specimen may be a tubular pipe. At this level a red-filmed type appears on a bowl shape.

Between the second level and third level Anderson recovered most of a short and rather wide-necked water bottle made of St. Johns paste. St. Johns Plain continues into the third level and there was also found a large amount of small check stamp which should be named St. Johns Check Stamp. From the surface have come a few specimens of an olive-green glazed ware, which may well be the fragments of Spanish olive jars.

The sequence of pottery wares and types as reported by Anderson conforms very well with that from the sites excavated by Wyman and Moore and with other excavations in the Southeast. South Indian Fields should yield very important confirmation of the above suggested ceramic stratigraphy and in addition has a number of other interesting prospects. From the level in which the fiber-tempered ware was found, Anderson obtained the jaws of the West Indian seal (*Monachus tropicalis*), and he claims that horse and mammoth bones also occur there. An extinct beaver and ground sloth remains were obtained from levels below the earliest pottery horizon.

Of much more limited distribution in the St. Johns drainage is a type found in the central part of the St. Johns, which is characterized by a curvilinear scroll design

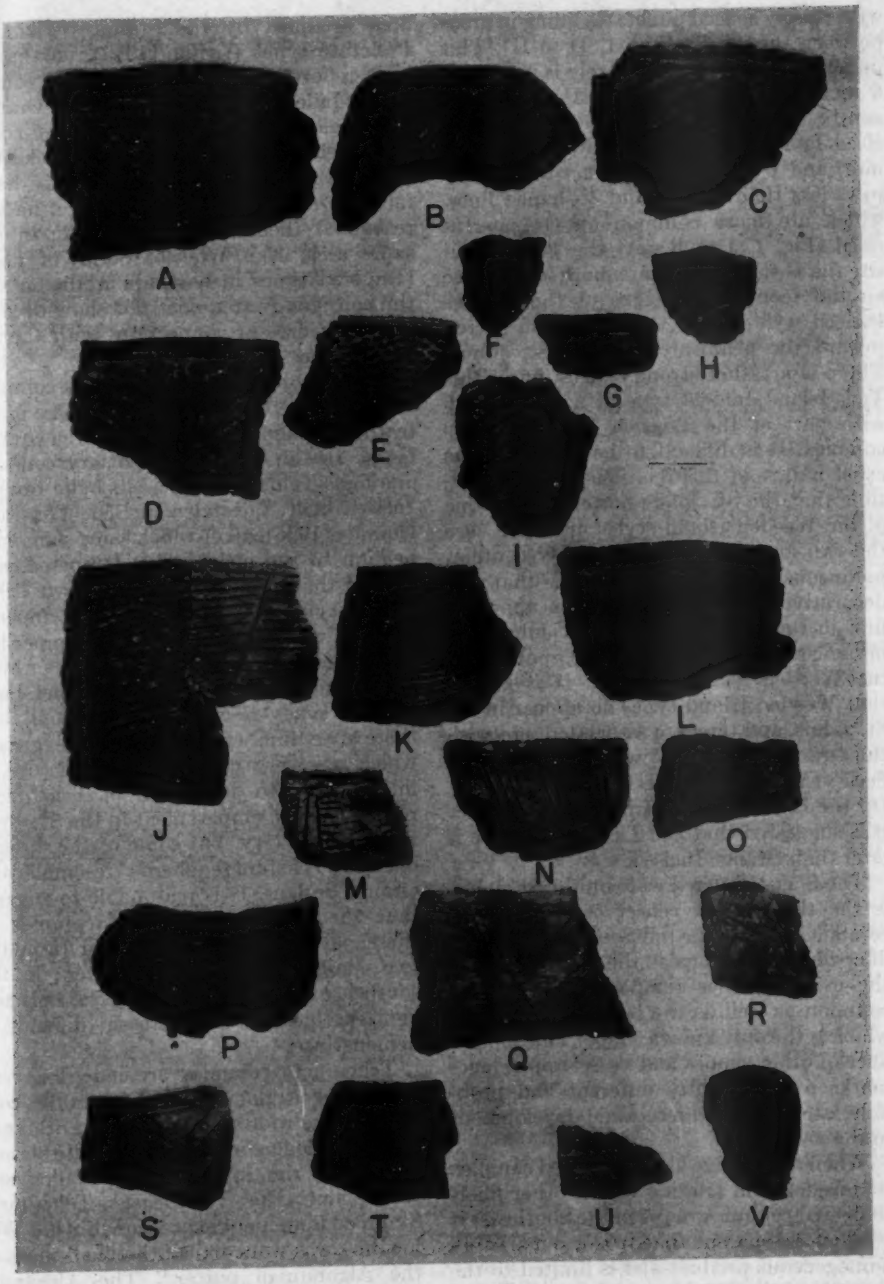

FIG. 1.—Sherds from the Tick Island site in the U. S. National Museum collection: A–C, Orange Incised with U-shaped lines; D–I, Tick Island Incised; J–R, Orange Incised; S–T, St. Johns Incised; U, mat impressed sherd on St. Johns paste; V, fragment of small bowl or ladle.

with closely spaced punctates filling in areas between the scrolls (Fig. 1, D to H). This punctate treatment very rarely is used with a rectilinear design (Fig. 1, I). This type can be called Tick Island Incised. The incised lines are usually medium-wide (2–4 mm) and U-shaped in contrast to the narrow (less than 2 mm) and V-shaped lines, which are more common on Orange Incised (Fig. 1, J to R). At the Tick Island site the U-shaped lines are more in evidence on the rectilinear designs of the Orange Incised style (Fig. I, A to C), than is true toward the headwaters of the St. Johns. There is a rather strong suggestion in this Tick Island Incised type of a relationship with part of the Weeden Island pottery complex. It is difficult to be certain of the exact nature of this relationship. It is possible that the St. Johns potters copied one of the Weeden Island styles, in which case the two groups would be roughly contemporaneous. Another possibility is that this decorative technique and design appeared first in the Southeast in the St Johns and became one of the concepts incorporated in the Weeden Island complex. It is known that Weeden Island types do appear in the St. Johns, and they are associated, not with the Orange Series, but with the St. Johns Series (Moore, 1896; pl. 75 is an example). On the basis of the distributional evidence it is suggested that the Tick Island type is later than Orange Incised.

The fiber-tempered ware on the St. Johns is the third major center of this earliest ceramic tradition in the Southeast. All the fiber-tempered groups in the Southeast have the use of fibrous tempering material in common as well as the bowl-shaped vessel which is the only known shape. The appearance of other shapes and vessel appendages marks a significantly different and probably later step in the ceramic development in the southeast.

When the Orange fiber-tempered complex is considered in relation to the other fiber-tempered ceramic groups in the Southeast it is at once apparent that it is a remarkably homogeneous product and is limited to the area along the Florida east coast from the mouth of the St. Johns to its headwaters. It does not occur much farther north into the area occupied by the Stallings Plain or Punctate types (Griffin, 1943), nor has it been reported from the area to the south. Willey failed to find evidence of the Orange Series along the Florida northwest coast (although some fiber-tempered sherds were reported), and Moore would hardly have failed to mention such specimens if he had recovered them in his excavation in the same area. The Wheeler Series of fiber-tempered types in northern Alabama and the contiguous area does not show decorative influences or connections with the St. Johns types.

There is one other early pottery complex in the south that does show in some of its features a definite connection to the Orange types. In the Tchefuncte pottery complex one finds Tchefuncte Incised, Lake Borgne Incised, and Alexander Incised (Ford and Quimby, 1935), all of which show some connection to the incised fiber-tempered pottery of the St. Johns. The first two Tchefuncte types are granular clay-tempered pottery, while sand was used to temper the Alexander type. Not all the designs or even the technique of the Tchefuncte and Lake Borgne types resemble Tick Island, but there are a number of sherds in both groups which are very close. The strong use of linear punctate decoration in Tchefuncte resembles such employment in the Stallings Punctate pottery, but some of the designs on the Tchefuncte sherds resemble the Orange designs. It is reasonable to suggest that the Tchefuncte pottery complex in these particulars was influenced from the two major fiber-tempered centers in the southeast rather than the reverse. It is recognized that this is at present difficult to demonstrate.

Tchefuncte ceramics are indeed a very interesting agglomeration of ceramic concepts from a wide area. Mandeville Stamped has its analogue in the early dentate stamping of the rim in the Illinois Valley and throughout the Northeast. Tchefuncte Stamped is an inept expression of what Willoughby was wont to call the "hall-mark of the Algonquian potter." The Alexander types are found to the east in Mississippi and Alabama and bear as one of their distinguishing features the Woodland punched

out boss along the upper rim. On the basis of the present evidence Tchefuncte could hardly be regarded as the origin of these various pottery practices.

In my paper that will accompany the Yale University volume on Florida a more exhaustive comparative statement will be compiled for the ceramic and cultural sequence in the East Florida area. At present the St. Johns fiber-tempered pottery can be recognized as one of the oldest types in the southeast; it contributed decorative techniques and designs to later ceramic levels in the area.

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ZOOLOGY.—*Four new species of North American crabs of the genus* Petrolisthes.[1]

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This paper describes three new species of *Petrolisthes* Stimpson from the Pacific and one from the Atlantic Ocean. Two of the species are new to the California coast but are neither obscure, rare, nor hard to obtain within their geographical limits. The new species from Panama, however, differs in this respect, its habitat being considerably restricted and local.

Petrolisthes manimaculis, n. sp.

Fig. 1

Not *Petrolisthes gracilis* Stimpson, Schmitt, Univ. California Publ. Zool. **23**: 181, pl. 32, fig. 4. 1921.

Types.—Male, holotype, and female, allotype, U.S.N.M. no. 79393, collected by the author from Morro Bay, Calif., at low tide, February 2, 1939.

Diagnosis.—Carapace nude, or lightly pubescent, lightly punctate, lateral margins roughened, front triangular, postocular tooth short, obtuse, no epibranchial spine, regions defined. Antennal flagellum smooth, blue. Carpus with sides subparallel, upper surface nearly smooth, or slightly roughened. Hands subsimilar, smooth, tuft of heavy pubescence in gape extending nearly to end on dactyl, less than halfway on pollex. Ambulatory legs with pubescence on upper margin of meri; merus of third leg twice as long as wide. In life, palp of maxillipeds blue, inner base of dactyl of cheliped orange, a median longitudinal row of blue dots on upper surface of palm.

Description.—Carapace in male slightly wider than long, female wider than male, depressed, regions defined, surface lightly punctate, punctae with microscopic pubescence, lateral regions lightly striate, no epibranchial spine, shoulders high, protogastric ridges divided by a median sulcus which deepens anteriorly, front triangular, slightly depressed, margins vertically sinuous, more than twice as wide as high, separated from upper orbital margin by a sulcus, upper margin roughened, tip blunt. Upper orbital margin elevated, no preocular tooth, postocular tooth obtuse, not

[1] Received March 14, 1945.

extending forward. First movable antennal peduncle armed with a cylindrical, tapered ridge, directed downward and outward, extending past distal extremity and slightly past proximal end of the cylindrical, smooth, second peduncle; flagellum smooth, almost nude, and more than twice the carapace width, color in life blue.

Chelipeds subsimilar, about three times the width of carapace in adult males, about two and a half times in females; merus with light transverse striae and a blunt, distal, inner lobe, not extending past inner margin of carpus; carpus nearly three times longer than wide in adult males, about two and a half times longer than wide in small specimens and females, margins subparallel, upper surface lightly roughened, a submedian, longitudinal elevation, outer margin rugose, with a sharp-pointed distal spine, some pubescence on the posterodistal half. Hands microscopically granular in adult males, more distinct in juveniles and females, inner margin an indistinct line of fine beading, outer margin blunt, sinuous, upper surface with a median, raised elevation, on which in life is a row of turquoise-blue dots. Dactyli unarmed, nearly as long as upper margin of palm, curved, sinuous, tips crossing pollex; a heavy felt of pubescence in gape which extends two-thirds the length of the underside of dactyl, and one-third the length of pollex; pollex unarmed.

Ambulatory legs with meri pubescent on upper crest, no posterodistal spine; merus of third leg twice as long as wide, other joints sparingly setose.

Sexual variation.—Female carapace wider, more areolate, rougher; carpus of cheliped more granulous, shorter; second antennal peduncle rough, granulated; ambulatory legs more pubescent; females smaller than males.

Color in life.—Ground color a rich brown, almost a red-chocolate, with large and small blue dots, giving the effect of blue lines, although they are actually a series of blue dots running together, this same effect being on the carpus and fingers of the hand. Median longitudinal ridge of the palm with a row of turquoise-blue spots. Legs a tan spotted with bluish white. Palp of maxillipeds margined with blue, inner proximal base of dactyl orange (Kirk).

Measurements.—Male holotype, carapace length 15.3 mm, width 16 mm; orbital width 8.5 mm; rostral width 3.5 mm, height 1.5 mm; antennal flagellum length 35 mm; major cheliped, length of carpus 16.5 mm, width 5.9 mm, length of hand 29 mm, width 11.5 mm; minor cheliped, carpus length 16 mm, width 5.5 mm, length of hand 29 mm, width 10 mm; merus of third ambulatory leg, length 8.5 mm, width 4.2 mm. Fingers nearly the length of palm.

Range.—San Francisco to San Diego, Calif.

Material examined.—The type series consists of several hundred specimens of both sexes, taken by the author at Morro Rock, Morro Bay, Calif., at low tide, on February 2, 1939. A series of about 50 specimens of both sexes, from Moss Beach, San Mateo County, Calif., taken in the latter part of May and the early part of June 1939 by R. Fields and E. Benton, under the direction of Dr. S. F. Light, of the University of California. Also a series of 30 specimens, both sexes, taken by the author at Spindrift Beach, La Jolla, Calif., at low tide, December 8, 1938. With the exception of distributed material all these specimens are in the author's collection.

Habitat.—This species occupies the lower levels of the intertidal zone. Its vertical range may be assumed not to exceed the mean low-water level. It, like most members of the genus, demands the shelter of rocks and weeds, uninfluenced by drifting sands. North of Point Conception, Calif., this species occupies an ecological horizon between *P. cinctipes* (Randall), which is above it, and *P. eriomerus* Stimpson, which is below. As neither *P. cinctipes* nor *P. eriomerus* is found south of Point Conception (except for the northernmost of the Channel Islands, San Miguel, Santa Rosa, and Santa Cruz), the southern association is changed, and *P. eriomerus* is replaced by *P. rathbunae* Schmitt, 1921, and *P. cabrilloa* Glassell (described as new in this paper) supplants *P. cinctipes*, although not in the same abundance.

Remarks.—This proposed species is allied to *P. eriomerus* Stimpson, 1871, but differs from that species in the following respects: (1) carapace without tubercles, (2) carpus two and a half to three times as long as wide, (3) carpus with upper surface smooth or slightly roughened, (4) inner base of dactyl of chelipeds orange (in *P. eriomerus* blue).

Stimpson's description of *P. gracilis*, by its brevity, has caused considerable confusion;

however, in the light of all the collections I have examined, it now appears to be a more or less localized species, restricted to the Gulf of California.

Petrolisthes cabrilloa, n. sp.

Fig. 4

Types.—Male, holotype, and female, allotype, U.S.N.M. no. 79391, collected by W. A. Kirk from Anaheim Landing, Calif., at low tide on October 11, 1939.

Diagnosis.—Carapace punctate, with light pubescence in punctae, striate on lateral margins; front triangular, obtuse, one-third as high as wide; postocular tooth short, obtuse, right-angled; no epibranchial spine; regions lightly indicated. Antennal flagellum ciliated, color ochre with purple edgings. Carpus about twice as long as wide, a proximal, inner marginal lobe, otherwise margins subparallel, upper surface pubescent, granulated. Hands subsimilar, granulated, a heavy tuft of pubescence in gape extending only halfway or less on both fingers. Ambulatory legs with pubescence and setae on meri. In life, palp of maxillipeds a brilliant orange, as is inner base of dactyli.

Description.—Carapace transversely flattened, convex fore and aft, small punctae in median areas and anteriorly, laterally striate, punctae microscopically pubescent, more prominent on front; protogastric ridges low, no epibranchial spine, shoulders moderately high. Posterolateral margins parallel. Front triangular, obtuse, three times as wide as high, slightly depressed, margins granulated, median sulcus, back to protogastric region, shallow. Upper

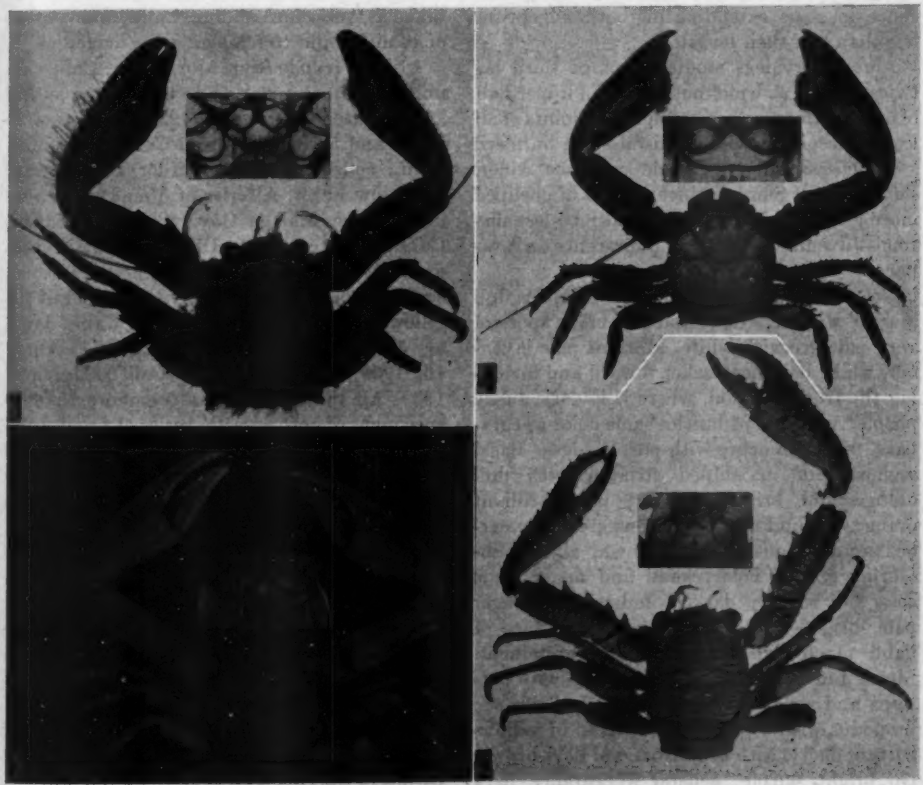

FIG. 1.—*Petrolisthes manimaculis*, n. sp., width of carapace 16 mm. FIG. 2.—*Petrolisthes tortugensis*, n. sp., width of carapace 11 mm. FIG. 3.—*Petrolisthes robsonae*, n. sp., width of carapace 8 mm. FIG. 4.—*Petrolisthes cabrilloa*, n. sp., width of carapace 11 mm. Inserts, fourth thoracic sternite.

orbital margin slightly raised, no preorbital spine, postorbital tooth obtuse, right-angled. First movable antennal peduncle armed with a blunt lobe, second peduncle cylindrical, granulated, flagellum compressed, ciliated, twice as long as carapace.

Chelipeds subsimilar, about three times the width of carapace; merus distally armed on inner side with a short, subvertical lobe, not extending forward past inner margin of carpus, surface lightly pubescent; carpus about twice the median width, inner proximal one-fourth with a lamellar lobe, rest of margins subparallel, upper surface granulated and pubescent, a strong posterodistal spine; hands granulated, but not rough, nude, inner margin not distinctly crested or beaded, outer margin smooth, sinuous, undersurface of palm highly polished, lightly punctate; fingers with a tuft of pubescence in gape extending on both fingers for less than half their length.

Ambulatory legs stout; merus of third leg twice as long as wide, pubescent on upper half of outer surface, setaceous on lower; joints of all legs setaceous, no posterodistal spine on meri.

Sexual variation.—Female carapace wider, slope of front more distinct; carpus of cheliped more granulated, inner proximal lobe less distinct. Juveniles with longer pubescence on carapace.

Color in life.—Ground color of carapace dull orange, with striations and numerous spots of very pale greenish white. Margins pale lavender, which becomes darker toward and including the frontal region, where it is dark dusky purple. Antennal peduncles same color as carapace, flagellum ochre with purple edges. Basal segments of maxilliped striated with dull orange and brilliant green; palp brilliant orange. Ground color of carpus green, numerous granulations reddish brown, almost obscuring ground color; hand and finger same color but slightly darker, underside of finger pale, bright, turquoise blue; undersurface of hand much lighter, with green prominent. Merus and carpus of ambulatory legs with patterns and striations light tan to dark brown, propodus with a broad center band of yellowish tan; dactyl with center band of dark brown, tip bright purple, general appearance dark dusky green. Ventral side pale dull yellow with darker patterns on abdomen (Petersen).

Measurements.—The measurements (in millimeters) are given for three specimens, respectively: the holotype male, the allotype female, and the largest female from Morro Bay. Length of carapace 11.4–10.1–12.1, width 11–10.5–13.1; orbital width 6.5–6.3–7.2; rostral width 3–3–3, height 0.9–0.6–1; length of flagellum 24–18–25; of major cheliped, length of carpus 10.2–7.7–9.6, width, proximal 4.8–3.6–5, median 4.2–3.6–4.3; length of hand 19–14.5–17.8, width at base of dactyl 8–6.2–7.6; of minor cheliped, length of carpus 9–7.1–9.5, width, proximal 4.2–3.5–4.8, median 4–3.3–4.3; length of hand 15.3–13–17.8, width 6.5–5.6–7.6; merus of third ambulatory leg, length 6.2–5.2–6.1, width 3.3–3.1–3.5.

Range.—From Point Conception, Calif., to Punta Banda, Baja California, Mexico (approximate).

Material examined.—The type series was taken at Anaheim Landing, Calif., and consists of 10 males and 10 females, some ovigerous.

A single female from Morro Bay, Calif. (see under *Measurements*), collected by the author at low water, February 2, 1939. A series of 50 males and 50 females, from Corona Del Mar, Calif., collected by the author December 9, 1938, low water. A series of 5 males and 5 females, from Malaga Cove, Palo Verde Hills, Calif., collected by Dr. Olga Hartman, February 2, 1939, low water. Also a number of small series of both sexes, taken by the author at the following localities: Point Dume, Calif., January 5, 1939; Topango Canyon, Calif., February 16, 1939; Sesquit Canyon, Calif.; March 4, 1939. All the above contained more than 10 specimens of both sexes. A series of 8 males and 6 females, collected by Paul Rich from the Star and Crescent Pier at San Diego, Calif., February 2, 1939. All the above material is in the author's collection.

Habitat.—Occupies the midtidal zone under shelter of rocks and is more tolerant of sand and muddy water than any of the other California species of this genus.

Remarks.—This proposed species has an affinity with *P. cinctipes* (Randall), 1839, but differs from that species in the following respects: (1) the ambulatory legs have their meri pubescent and setose, instead of nude; (2) the carpus of the chelipeds is twice as long as wide, the proximal lobe small, the margins otherwise subparallel, instead of being one and one-half times as long as wide, margins converging dis-

tally; (3) the carapace is pubescent in juveniles, instead of nude.

Named for Juan Rodriguez Cabrillo, a Portuguese navigator in the service of the King of Spain, who in ill-fitted boats on an uncharted sea discovered a golden empire, and left his bones in an unmarked grave on the windswept island of San Miguel, annò 1542. *Un hombre valiente, saludes.*

Petrolisthes robsonae, n. sp.

Fig. 3

Types.—Male, holotype, and female, paratype, U.S.N.M. no. 79396, collected by Elinor D. Robson from Miraflores Locks, Panama Canal, Canal Zone; March 26, 1937.

Diagnosis.—Carapace lightly roughened, lightly pubescent; front broadly triangular, horizontal; an epibranchial spine. Chelipeds with inner margin of carpus armed with two spines; manus with outer margin concave, spined. Posterodistal end of meri of first and second ambulatories with two spines, upper distal end of carpi with one spine.

Description.—Carapace slightly longer than wide, sides rounding, margin behind the single, sharp, epibranchial spine forming a sharp, indistinctly beaded ridge. Surface very lightly rugose, with or without very light pubescence. Front subhorizontal, slightly advanced, broadly triangular, subentire, a median shallow sinus running back onto the gastric regions dividing the protogastric ridges. The upper ocular margin is lightly beaded, the postorbital tooth a right-angle. First antennal peduncle with a horizontally compressed, distal lobe armed with a single large spine and several smaller spines, the distal end of this lobe rounded and extending past the articulation of the second peduncle, which has a crested ridge, the proximal end the highest. Flagellum nude, two and a half times the length of the carapace.

Chelipeds subequal in the female, differing in the adult male, surfaces lightly roughened with short lines of rugae; merus with an inner distal lobe and a single marginal spine on the upper edge near the outer side; carpus nearly two and a half times as long as wide, subhorizontal on upper surface with a longitudinal median ridge, inner margin armed with two spines, the proximal the largest, the second located in a submedian position, the margin microscopically serrate. In young specimens there is an indication of a third tooth near the distal end, but this is obsolete even in half-grown specimens. Outer margin armed with a sharp, posterodistal spine, a single distal marginal spine, and one or two subdistal outer marginal spines. Manus triangular, rather flattened in the female, rounded in the male, the inner margin revolute, the outer concave and armed with long, sharp-pointed spines extending onto the pollex in the female, ending before the pollex in the male. In addition to these spines there is a fringe of cilia and pubescence covering the outer half of the lower surface of the palm and a dense felt of pubescence extending half the length of the fingers. Major hand of the male with the fingers gaping, blunt, tips not crossing. Minor hand in the male and both hands in the female with fingers approximated for their length, the tips crossing.

Ambulatory legs with their meri lightly crested with pubescence, the remaining joints with sparse setae; a single, sharp, long, flat-lying spine on the upper crest, one-third the distance from the distal end; two spines, one above the other, at the posterodistal end of the meri of the first and second legs. A distal spine on the upper crest of the carpus in all three legs. Propodi in the first two pairs bent forward.

Abdomen heavily fringed between the first four segments. Telson with seven plates, the terminal pair distally separated by a wide V-shaped commissure.

Color in alcohol.—In those specimens on which the pubescence remains the color is a dark brown; in rubbed specimens a distinct pink tone is noted.

Measurements.—Male holotype: length of carapace 8.6 mm, width 8 mm, length of carpus 7.4 mm, width not including teeth 2.8 mm, length of major hand 12.6 mm, width at base of dactyl 5 mm, length of minor hand 12.1 mm, width 4.2 mm, length of major dactyl from joint to tip 4.5 mm, of minor dactyl 5 mm, length of antennal flagellum 21 mm.

Range.—Known only from type locality.

Material examined.—A series of 17 males and 20 females, some ovigerous, all collected at the same time and locality by Mrs. Robson.

Habitat.—Mrs. Robson, after whom the species is named, informs me that it has so far been taken only inside the canal locks during one of their periodic cleanings. It is amazing to me to consider this location as suitable for

Petrolisthes, as I am informed that the water within these locks is continuously being changed, its saline content varying from almost fresh to that of sea water. This change from salt to fresh water argues for an almost unbelievable tolerance on the part of this species to fresh water, a substance lethal to other species of the genus within a short period of time, usually half an hour or more, during which time the membranes are ruptured by osmosis.

Exact information, however, as to the ecology and as to the salinity of the water at the place of capture is not yet available.

Remarks.—This proposed species is allied to *P. armatus* (Gibbes), 1850, but differs from that species in the following respects: (1) by having only two carpal spines, (2) by having only one spine on the upper crest of the meri of the ambulatory legs, (3) by the underside of the hands being half covered with hair, (4) and by the outer margin of the hands being concave and fringed with hair.

This proposed species is dedicated to Mrs. Elinor D. Robson, who has shown a marked interest in the fauna of the Canal Zone.

Petrolisthes tortugensis, n. sp.
Fig. 2

Types.—Male, holotype, U.S.N.M. no. 79395, collected by Dr. Waldo L. Schmitt, at Tortugas, Fla., 8.5 fathoms, July 19, 1924. Three paratypes, 2 males and 1 female, in the author's collection. All other paratypes in the U. S. National Museum (see under *Material examined*).

Diagnosis.—Carapace longer than wide, transversely striate, an epibranchial spine, a branchial spine, lateral margins spined, rostrum obtusely triangular, spined, depressed. Chelipeds long and narrow; upper inner carpal margin 4-spined, lower inner margin with one or two; hands narrow, with spinate outer margins; fingers distorted, with spooned apices, gaping. Ambulatory legs with propodi one-fifth shorter than meri; meri spine crested, numbers 1 and 2 with two posterodistal spines, number 3 with one. Antennal flagellum slender, nonciliate, more than three times carapace length.

Description.—Carapace longer than wide, transversely striate, transversely convex, with an epibranchial spine, a postocular spinule, three lateromarginal, forward- and upward-pointing spines and one on the carapace inside of these and nearer to the third or proximal marginal spine. Rostrum medially depressed, obtusely triangular, and armed on and upon its anterior margin with spines and spinules as follows: an ocular spine, a preocular spine, then two marginal spines, followed by two inner marginal spines, then an upward- and inner-curving spine, and lastly one or two more smaller spines and spinules at the apex. A shallow median sulcus running backward by the subobliterated protogastric lobes. Eyes large and black, their width about one-fifth the carapace length. First movable antennal segment armed on its inner margin with a long, vertically compressed, median spine and a smaller distal spine, the second segment granulous, the third smooth, the flagellum nude, slender, hairlike, and over three times the carapace length.

Chelipeds dissimilar, slender, striate both above and below, their length about three times that of the carapace; ischium armed on its inner ventral margin with a row of three or four spines, the proximal pair the largest; merus with a prominent, sharp spine at its distal, inner, dorsal angle and another below this on the ventral margin, the upper, transverse margin armed with two well-spaced spines; carpus almost three times as long as wide, measured without the spines, its upper surface lightly convex and lacking a longitudinal median ridge, the inner margin armed with four large, sharp-pointed teeth and a distal spinule, their proximal margins longer than their distal, the ventral inner margin armed with one or two spurlike spines on its distal two-thirds, the upper outer margin armed with a row of five short, upward- and forward-pointing spines; the hands dissimilar, that of the major one-third as wide as long, that of the minor one-fourth, their outer margins concave and armed with spinules, the inner margins with light beading, terminating over the base of the movable finger in a sharp spine, the pollices outwardly convex, their tips longitudinally truncate and spooned, the dactylus of the major hand ending in a curved tip that crosses an outer spine on the apex of the pollex, armed on its inner proximal half with two compressed, truncate teeth, which do not engage

the pollex, as in both hands the fingers are widely gaping, the minor dactylus twisted, armed on its upper crest with a row of spinules ending in a falcate tip which crosses the spooned tip of its pollex, its prehensile edge unarmed and the widely spread gape setaceous. The spoon-shaped tips of the fingers with pectinate margins.

Ambulatory legs relatively slender and nude except for a few scattered setae; meri crested with a row of short spines, the distal postero-angle of numbers 1 and 2 are armed with two spines, of number 3 with one spine, in length more than twice their width; the propodi cylindrical, slightly bent, and one-fifth shorter than their meri; the dactyli corneous-tipped and one-half the length of their propodi. Telson composed of 7 segments, in the male apparently formed with 8, the proximal, median triangular portion being transversely divided by a ridge, these two parts, however, coalesced as in *P. galathinus* (Bosc), with which it is associated.

Color in alcohol.—Ground color cream, suffused with rose-pink, especially on all striations and squamae. Ambulatory legs rose-pink, with a median, transverse band of cream on meri and propodi; the distal ends of all segments tipped with cream.

Measurements.—A male paratype, carapace length 6.8, width 6.5; major cheliped 23.5, carpus length 6.5, width without spines 2.4, manus length 10.5, width at base of finger 3.8; minor cheliped, carpus 6, width 2.3, manus 10, width 2.6; first ambulatory leg, length 11, merus 3.7, carpus 1.7, propodus 3.3, dactylus 2; width of eye 1.2; length of antennal flagellum 24 (all measurements in millimeters).

Range.—Known only from type locality (see under *Types*).

Material examined.—A series of 23 specimens: 10 males, 11 females (mostly ovigerous), 2 juveniles. All collected in and around Tortugas, Fla., by Dr. Waldo L. Schmitt, and mostly during the month of June 1931.

Sexual variation.—In the female the chelipeds are much narrower than in the male and are more similar to each other, as in the juveniles of both sexes; however, the dactylus of the major cheliped is the only one of the two which has teeth in the gape.

Habitat.—Taken from *Porites* clumps from extreme low water to a depth of 11 fathoms, mostly from 8 to 11 fathoms.

Remarks.—This proposed species resembles in some respects those placed in the genus *Petrocheles* Miers, in that the lateral margins are spined, the chelipeds long and narrow, the fingers gaping, and rostrum spinate; however, it would seem that there is reason to believe that *Petrocheles* should not have been elevated to full generic standing but left as Miers intended it, as a subgenus of *Petrolisthes*, a course which, from lack of comparative material, I am inclined to follow. It is not allied to many of the American *Petrolisthes*, from all of which it differs in the peculiar spoon-shaped finger tips, reminiscent of a number of forms among the Galatheidae, which in addition display the compressed, truncate teeth that arm the dactylus of the major chela, a character that few if any of the *Petrolisthes* possess.

It is the Atlantic analogue of *P. sanfelipensis* Glassell (Trans. San Diego Soc. Nat. Hist. 8 (21): 281. 1936) from the upper end of the Gulf of California. Both have slender chelipeds, spines on the lateral margins of the carapace, and a spinate rostrum, but the present species differs in that (1) the fingers are spoon-tipped, gaping, and twisted, instead of close-fitting, falcate-tipped, and unarmed in the major dactylus, (2) the line of the rostrum from the ocular spine to its apex is subentire instead of emarginate below the preocular tooth, (3) the inner ventral margin of the carpus of the chelipeds is armed with teeth, instead of being unarmed, and (4) the posterodistal angle of the merus of the third ambulatory leg is spined instead of being unarmed.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

47TH ANNUAL MEETING

The 47th annual meeting of the Academy, held in the Auditorium of the Cosmos Club, January 18, 1945, after the 330th meeting of the Academy, was called to order at 9:45 P.M. by the President, Capt. CLEMENT L. GARNER, with 33 persons in attendance.

The minutes of the 46th annual meeting were approved as published in the JOURNAL 34: 198–205. 1944.

The reports of several officers and of the Committees of Auditors and Tellers were read and accepted. These reports are recorded at the end of the minutes.

After the acceptance of the report of the Committee of Tellers, the President declared the following duly elected to the given offices:

JOHN E. GRAF, *President*
F. G. BRICKWEDDE, *Secretary*
HOWARD S. RAPPLEYE, *Treasurer*
HENRY B. COLLINS, Jr., and JAMES TAYLOR, *Board of Managers to January 1948*

The Secretary presented for the Affiliated Societies their nominations for Vice-Presidents of the Academy as follows:

Philosophical Society of Washington—GEORGE R. WAIT
Anthropological Society of Washington—T. DALE STEWART
Biological Society of Washington—FRANK THONE
Chemical Society of Washington—HORACE S. ISBELL
Entomological Society of Washington—CARL F. W. MUESEBECK
National Geographic Society—ALEXANDER WETMORE
Geological Society of Washington—GEORGE TUNELL
Medical Society of the District of Columbia—FREDERICK O. COE
Columbia Historical Society—GILBERT GROSVENOR
Botanical Society of Washington—FRANK P. CULLINAN
Archaeological Society of Washington—Not functioning for the duration of the National Emergency
Washington Section of the Society of American Foresters—WILLIAM A. DAYTON
Washington Society of Engineers—FRANK B. SCHEETZ
Washington Section of the American Institute of Electrical Engineers—FRANCIS B. SILSBEE
Washington Section of the American Society of Mechanical Engineers—WALTER RAMBERG
Helminthological Society of Washington—MARIO MOLLARI
Washington Branch of the Society of American Bacteriologists—HAROLD R. CURRAN
Washington Post of the Society of American Military Engineers—CLEMENT L. GARNER
Washington Section of the Institute of Radio Engineers—HERBERT GROVE DORSEY
Washington Section of the American Society of Civil Engineers—OWEN B. FRENCH

The Secretary was instructed by the members present to cast a unanimous ballot for these nominees.

The President, Capt. CLEMENT L. GARNER, announced the recipients of the Academy's Awards for Scientific Achievement for 1944 as follows:

In the Biological Sciences to NORMAN H. TOPPING, National Institute of Health, in recognition of his outstanding work in identifying eastern and western types of Rocky Mountain spotted fever.

In the Engineering Sciences, to GALEN B. SCHUBAUER, National Bureau of Standards, in recognition of his distinguished services in aeronautical engineering, particularly for fundamental measurements of turbulence.

In the Physical Sciences, to GEORGE GAMOW, George Washington University, in recognition of his distinguished service in theoretical physics, particularly in the understanding of atomic nuclei and of stars.

The Retiring President, Capt. CLEMENT L. GARNER, appointed Past Presidents HARVEY L. CURTIS and LELAND W. PARR to escort the incoming President, JOHN E. GRAF, to the Chair. After a few brief remarks, Mr. GRAF adjourned the meeting at 10:30 P.M.

The following reports were presented at the meeting:

Report of the Secretary

During the Academy year 43 persons (38 resident and 4 nonresident) were elected to membership. Of these, 25 resident and 1 nonresident qualified for membership, 3 resident and 1 nonresident accepted membership but have not yet qualified by payment of dues, 1 resident and 2 nonresident have not yet re-

plied to the Secretary's notification of election, and 3 persons declined membership. Seven other persons of the 43 elected during the Academy year were elected so recently they have not had time to reply. Seven persons elected to resident membership in the preceding Academy year qualified during the present Academy year just ending. The new members were distributed among the various sciences as follows: 6 in anthropology; 4 in geophysics; 3 each in botany, chemistry and geology; 2 each in mathematics, mechanical engineering, mineralogy, and physics; 1 each in bacteriology, chemical physics, hydrography, ichthyology, paleontology, and geography.

Eight members of the Academy (6 resident and 2 nonresident) having retired from the active practice of their profession were placed on the retired list to enjoy all the privileges of active membership without further payment of dues. Three members (2 resident and 1 nonresident) resigned in good standing. Eight resident members were dropped for nonpayment of dues.

The deaths of the following 13 members (7 resident and 6 nonresident) were reported to the Secretary:

SOFIE A. NORDHOFF-JUNG, Washington, D. C., June 6, 1943.
J. MCKEEN CATTELL, Lancaster, Pa., January 20, 1944.
EDWARD B. MATHEWS, Baltimore, Md., February 4, 1944.
ARTHUR KEITH, Washington, D. C., February 7, 1944.
EDWARD O. ULRICH, Washington, D. C., February 22, 1944.
GEORGE STEIGER, Washington, D. C., April 18, 1944.
ROGER C. WELLS, Washington, D. C., April 19, 1944.
WILLIAM M. CORSE, Washington, D. C., June 3, 1944.
HARRY F. REID, Baltimore, Md., June 18, 1944.
J. FRANKLIN MEYER, Washington, D. C., October 29, 1944.
HARRY V. HARLAN, Sacaton, Ariz., November 6, 1944.
GEORGE W. COGGESHALL, Cambridge, Mass., November 19, 1944.
LYSTER H. DEWEY, Kenmore, N. Y., November 29, 1944.

Of these, ARTHUR KEITH and LYSTER H. DEWEY were original members of the Academy.

On January 17, 1945, the status of membership was as follows:

	Regular	*Retired*	*Honorary*	*Patron*	*Total*
Resident.....	429	36	2	0	467
Nonresident...	142	26	16	1	185
Total.....	571	62	18	1	652

The net changes in membership during the past year are as follows:

	Regular	*Retired*	*Honorary*	*Patron*	*Total*
Resident.....	0	+1	0	0	+1
Nonresident...	+7	+1	0	0	+8
Total.....	+7	+2	0	0	+9

During the Academy year 1944 the Board of Managers held 7 meetings, with an average attendance of 20 persons. The following important matters were considered by the Board:

(1) The American Association for the Advancement of Science made available to the Academy during the year a grant of $207.50 for assisting members of the Academy and its Affiliated Societies with research projects in need of funds. This added to the grant of $150 made available in the preceding year makes a total of $357.50 now available to the Academy for assisting deserving research projects. The actual funds remain with the A.A.A.S. until these projects are selected. The Board of Managers voted to receive applications for grants in support of research. The Secretaries of the Affiliated Societies were notified and an announcement was published in the November 1944 issue of the JOURNAL. Applications will be received until February 1, 1945. FRANK H. H. ROBERTS, JR., is chairman of the Committee on A.A.A.S. Grants. Other members of the Committee are: L. W. PARR, R. J. SEEGER, and R. P. TITTSLER.

(2) The Red Book was not published this year because of difficulties arising out of the present emergency. Progress, however, on the publication of the next issue of the Red Book is being made by the Treasurer who has initiated and is preparing a continuing up-to-date list of names with home and business addresses, when both are available, of the members of the Academy and its Affiliated Societies.

During the Academy year, 7 meetings of the Academy were held as follows, beginning with the 324th meeting and ending with the 330th meeting:

On February 17, 1944, LELAND W. PARR, as retiring president, presented an address entitled

Aspects of epidemiology of tuberculosis. (This JOURNAL 34: 169–181. 1944.)

On March 16, 1944, the 1943 Academy Awards for Scientific Achievement were presented to JASON R. SWALLEN, Office of the Coordinator of Inter-American Affairs, for work in the biological sciences; to LLOYD V. BERKNER, commander, U.S.N.R., for work in the engineering sciences; and to LAWRENCE A. WOOD, National Bureau of Standards, for work in the physical sciences.

On April 20, 1944, GERALD FITZGERALD, lieutenant colonel, chief, Aeronautical Chart Service, Army Air Forces, addressed the Academy on *Reconnaissance mapping with trimetrogon.*

On October 19, 1944, J. EDWARD RAUTH, associate professor of psychology, Catholic University of America, addressed the Academy on *The eidetic image.*

On November 30, 1944, ROBERT H. MONTGOMERY, economic adviser, Foreign Economic Administration, addressed a joint meeting of the Philosophical Society of Washington and the Academy on *The impact of technology on community life.*

On December 21, 1944, SCOTT B. RITCHIE, colonel, assistant chief of ordnance, U. S. Army, addressed the Academy on *New developments in ordnance.*

On January 18, 1945, HERBERT FRIEDMANN, curator, Division of Birds, U. S. National Museum, addressed the Academy on *A symbolic goldfinch, a study in medieval ornithology as expressed in art.*

All seven meetings were held in the Assembly Hall of the Cosmos Club.

F. G. BRICKWEDDE, *Secretary.*

Report of the Treasurer

CASH RECEIPTS AND DISBURSEMENTS

RECEIPTS		
From dues 1940	$ 5.00	
From dues 1941	10.00	
From dues 1942	30.00	
From dues 1943	71.67	
From dues 1944	2,692.06	
From dues 1945	35.00	$2,843.73
From life memberships (2)		126.85
From JOURNAL, Subscriptions, 1940	5.40	
From JOURNAL, Subscriptions, 1941	11.40	
From JOURNAL, Subscriptions, 1942	22.80	
From JOURNAL, Subscriptions, 1943	46.20	
From JOURNAL, Subscriptions, 1944	353.85	
From JOURNAL, Subscriptions, 1945	468.90	
From JOURNAL, Subscriptions, 1946	4.05	912.60
From sales of JOURNAL		227.90
From payments for reprints 1943	122.31	
From payments for reprints 1944	528.46	650.77
From sales of directory, prior to 1941	1.05	
From sales of directory, 32d Edition	0.25	1.30
From interest on investments		1,017.25
From check No. 170—"Outlawed"		21.50
From repayment of withholding on New York City Stock		4.60
From refund of air-mail postage		0.70
From overpayment by Shapovalov		0.35
Total Receipts		$5,807.55
Cash balance, Jan. 1, 1944		3,028.64
To be accounted for		$8,836.19
DISBURSEMENTS		
For Secretary's Office 1943	$ 200.90	
For Secretary's Office 1944	87.59	$ 288.49
For Treasurer's Office 1944		86.31
For Custodian & Subs. Mgr. 1944		62.83
For JOURNAL printing and mailing 1943	231.68	
For JOURNAL printing and mailing 1944	2,495.86	2,727.54
For JOURNAL illustrations 1943	10.94	
For JOURNAL illustrations 1944	223.36	234.30
For JOURNAL reprints 1943	66.75	
For JOURNAL reprints 1944	531.71	598.46

For JOURNAL office 1943	40.00	
For JOURNAL office 1944	220.00	260.00
For JOURNAL postage, binding & misc. 1943	4.35	
For JOURNAL postage, binding & misc. 1944	22.60	26.95
For Directory 1943		19.50
For Meetings Committee 1943	52.15	
For Meetings Committee 1944	232.20	284.35
For two $1,000 Series G Bonds		2,000.00
For debit memos, refunds, etc.		2.66
Total disbursements		$6,591.39
Cash balance, Dec. 31, 1944		2,244.80
Total		$8,836.19

RECONCILIATION OF BANK BALANCE

Balance as per cash book, 12-31-44		$2,244.80
Bank Balance, Am. Soc. & Tr. Co. as per statement 12-23-44	$2,223.86	
Receipts not deposited	149.67	
	$2,373.53	
Checks outstanding, not cashed		
No. 1018	$ 5.41	
1028	55.20	
1029	51.50	
1030	16.62	
	128.73	$2,244.80

INVESTMENTS

409 Shares stock of Washington Sanitary Improvement Co., par value $10 per share, cost	$4,090.00
20 Shares stock Potomac Electric Power Co., 6% Pref., cost	2,247.50
4 Certificates Corporate Stock of City of New York, 1 for $500, 3 for $100, cost	800.00
1 Bond of Chicago Railways Co., #1027; interest at 5%, due 1927, par value $1,000, less $250 paid	750.00
2 Real-estate notes of Yetta Kormann et al., dated Oct. 5, 1938, renewed 1941 for 3 years (#7 of 37 for $500 and #8 of 37 for $500), cost	1,000.00
2 Certificates (1 for $4,500 and 1 for $500) Northwestern Federal Savings & Loan Assn. Nos. 1380 and 1441	5,000.00
2 Certificates (1 for $4,000 and 1 for $1,000) First Federal Savings & Loan Assn. Nos. 914 & 1063	5,000.00
7 U. S. Government Series G Bonds at $1,000 each, Nos. M332990G M332991G M332992G M332993G M1808741G M2226088G M2982748	7,000.00
Deposited in Savings Account, American Sec. & Trust Co.	46.87
	$25,934.37
Cash Book balance Dec. 31, 1944	2,244.80
Total Assets	$28,179.17

Total Assets Dec. 31, 1943	$26,962.79	
Total Assets Dec. 31, 1944	28,179.17	
Increase	$ 1,216.38	

The relatively large increase in the assets of the Academy is not actually as large as shown. It is impossible at the close of the fiscal year to know exactly what bills are outstanding. We can not even furnish an exact statement as to the relationship between expenditures and allotments, since, for example, we do not yet know exactly what the charge-to-authors increment of the JOURNAL allotment will be. The statement concerning the status of the various allotments will be submitted later as a supplemental report. It is known, however, that, at the time this report is written, $236.77 has been paid out since January 1, 1945, on obligations incurred in 1944 and chargeable to 1944 expenditures. Also, there are some of the George Banta Publishing Co. bills which have not yet been received. However, making due allowance for this feature, the report shows a healthy increase in the assets of the Academy, which is due, to a considerable extent at least, to the fact that various officers and officials of the Academy have exercised care to keep their expenditures well within their allotments. Perhaps one of the most important single reasons for the increase in assets shown in this report and in the report for the previous year is the fact that we have not issued a Red Book since 1941. The Treasurer's Office is at present at work on a master list which should permit

the resumption of the publication of the Red Book by the latter part of this year or the early part of 1946. It is believed that, under the new arrangements, which are being perfected to expedite the publication of the Red Book, future Red Book costs will be even less than the cost of previous issues in spite of higher printing costs.

HOWARD S. RAPPLEYE, *Treasurer.*

Report of the Auditing Committee

Your committee appointed to audit the accounts and records of the Treasurer for the calendar year 1944 performed that duty on January 11, 1945. Each item of disbursement was found to be duly authorized and supported by a cancelled check or debit memorandum except for the outstanding checks listed in his report. The Treasurer's report, attached hereto, was found to agree in every respect with his records.

The securities listed in his report were examined on January 11, 1945, and were found to be as listed. All unmatured coupons were found attached.

The Treasurer deserves the hearty commendation of the Academy for the careful, systematic, and accurate records which he has kept.

FRANCIS A. SMITH, *Chairman.*
WALTER D. LAMBERT
HARALD A. REHDER.

Report of the Archivist

The archives are stored in Room 113, Soils Building, U. S. Plant Industry Station, Beltsville, Md., in a steel safe, a metal file cabinet, a wooden file cabinet, and two bookcases. The wooden file cabinet belongs to the Academy; the other furniture is borrowed for the duration. No expense was incurred during the year and none is contemplated for the next year.

NATHAN R. SMITH, *Archivist.*

Report of the Board of Editors

Volume 34 of the JOURNAL was somewhat larger than that of the preceding year and showed trends in different directions from those of previous years. Some of these trends are probably not normal or permanent but are connected with dislocations brought about by the war. Volume 34 consisted of 12 issues and contained 416 pages distributed among the sciences and compared with 1943 as shown in the table below.

This volume includes the addresses of the retiring presidents of the Academy and the Philosophical Society as well as an address delivered before the Academy during the previous year. A total of 63 papers was published, which is a slight decline in the number of 65 for 1943. This small loss is offset by the greater length of some of the papers accepted for publication during this year. Of the 63 papers presented 35 or 56 percent were presented by members of the Academy. This represents a small decrease in papers presented by Academy members, a condition that should be corrected.

Volume 34 shows small increases in numbers of halftones and pages. Sixteen halftones and 36 line-cuts appear in the volume. The slight increase in the former was made possible by an increase in appropriation that permitted the Editors to drop the unfortunate ban on free halftones of the last two volumes. Volume 34 contains 28 more pages than appeared in volume 33. This is the most satisfactory trend shown during the year and if possible should be encouraged to continue. The downward trend in number of pages published in the

Sciences	No. papers 1944	No. pages 1944	Percentages by pages 1944	No. papers 1943	No. pages 1943	Percentages by pages 1943
Biological	40	198.2	47.6	56	293.8	75.4
Physical	3	35.9	8.6	7	47.6	12.4
Anthropological	12	105.6	25.4	—	—	—
Geological	5	13.8	3.3	—	—	—
Medical	2	22.5	5.4	—	—	—
Economic	1	2.8	.0.7	—	—	—
General	—	—	—	2	17.8	4.6
Obituaries and Proceedings	—	33.2	8.0	—	25.4	6.6
Index	—	4.0	1.0	—	3.4	1.0
Totals	63	416.0	100.0	65	388.0	100.0

JOURNAL at present seems to have been arrested, but it is hoped that the future will see a still more substantial increase in number of pages published.

As would be expected in these abnormal times the war has greatly affected the proportional representation of the sciences in the JOURNAL. The Biological Sciences predominate as they did last year, but they are proportionally much less this year to the other sciences represented. Unlike last year when botanical papers were most numerous, zoological papers (12) are most frequent this year. Botany takes second place with 10 papers and entomological articles are third with 9. Other Biological Sciences represented are: Ichthyology, Mycology, Ornithology, Mammalogy, and Ecology.

Because Chemistry and Physics are closely linked to the war effort, it is not surprising that these sciences are even less well represented in Volume 34 than they were in Volume 33. Inasmuch as the physical scientist's preoccupation with war problems will continue for at least another year, no increase in papers from these sciences can be expected.

Five papers are attributed to the Geological Sciences but these could as well have been placed under the Biological Sciences because they all deal with fossils. Most of the efforts of our geologists in Washington are now directed along lines designed to facilitate the war effort. Consequently the decline in geological papers, which are usually fairly numerous, is understandable.

During the past year an increase of considerable proportions occurred in papers dealing with Man and his activities—Anthropology, Ethnology, Economics, and Medicine. Fifteen papers in these fields constituted some of the most interesting items published during the year and occupied more than 31 percent of the pages published. It is to be hoped that this trend will continue to expand after the war.

Preoccupation with war and generally restricted time account for a decline in published abstracts. The Geological and Botanical Societies, both usually regular contributors, failed to submit their proceedings and abstracts, the latter for at least the third year. The Editors report the publication of 18 obituaries, the largest number to appear for several years.

The year 1944 happily saw little change in editorial policy and what little occurred proved highly advantageous to the JOURNAL and its contributors. A thoughtful increase in the appropriation for the year made it possible to offer authors a full page halftone or its equivalent. Lack of adequate facilities to reproduce illustrations proved a handicap in 1943; it discouraged authors who required halftone illustration. The economies instituted in 1942 continued in force except for the changes relating to halftones and the distribution of 50 free reprints to authors of signed obituaries. The Editors view with considerable satisfaction the fact that it was possible to issue the JOURNAL on a monthly basis, but papers are becoming increasingly fewer and it may be necessary in future to put the JOURNAL on a bimonthly basis on authority voted by the Board of Managers in 1943. This, the Editors believe, would be most unfortunate and they plead with Academy members to give their JOURNAL first consideration in placing their shorter papers. Why should more than 40 percent of the JOURNAL'S pages be used by outsiders?

The Board of Managers appropriated to the Board of Editors for printing, illustrating, and mailing the JOURNAL $3,000; for clerical assistance $240; and for postage and incidentals $60, a total of $3,300. Of this sum the total amount of $240 for clerical assistance was expended; postage and incidentals (binding volume 33 of the Editors' set of the JOURNAL) required $25.59. Printing, mailing, and illustrating the JOURNAL cost $2,981.69. Reprints cost $592.70. Charges to authors were $746.51. This sum combined with the original allotment of $3,000 equals a total available sum of $3,746.51. Subtracting from this total the $3,574.39 paid out, a favorable balance of $172.12 remains. This added to the balance of $34.41 remaining from postage and incidentals leaves a final favorable balance of $206.53.

It gives the Editors much pleasure to acknowledge with thanks and appreciation the outstanding assistance to the JOURNAL of Mr. PAUL A. OEHSER, editorial assistant, whose broad knowledge and experience in editing scientific articles have greatly improved the quality of the JOURNAL. Mr. Oehser has given much wise council and many hours of his own time.

G. ARTHUR COOPER.
LEWIS V. JUDSON.
HARALD A. REHDER.

Report of the Custodian and Subscription Manager of Publications

SUBSCRIPTIONS:

Nonmember subscriptions in the United States	107
Nonmember subscriptions in foreign countries	35
Nonmember subscriptions in enemy-controlled areas (inactive)	25
Subscriptions, Geological Society of Washington	12

INVENTORY OF STOCKS AS OF DECEMBER 31, 1944:

Reserve Sets of the JOURNAL:	
Bound Volumes 1–29 and unbound Volumes 30–34	1 set
Unbound Volumes 1–34	4 sets
Unbound Volumes 11–34	6 sets
Unbound Volumes 16–34	11 sets
Proceedings of the Washington Academy of Sciences: Volumes 1–13, inclusive	50 sets

In 1939 the Board of Managers directed the Custodian of Publications to set aside a specific number of volumes of the JOURNAL to be sold only as complete sets. This order states: Eight (8) complete sets from Vol. 1 to current volumes (34); Six (6) additional sets from Vol. 11 to current volumes (34); Eleven (11) additional sets from Vol. 16 to current volume (34). These volumes should constitute the reserve sets. Since 1939 five reserve sets from Vol. 1 to the current number have been sold. Three of these sets were sold in 1944. When disposing of back numbers of those of deceased members, some of our members have turned them over to the Custodian of Publications, which enabled him to assemble two complete sets from Vol. 1 to the current number. During the coming year an effort will be made to obtain by gift or purchase some of the early numbers now missing from the miscellaneous series in order to assemble additional reserve sets.

A miscellaneous series of volumes and separate numbers of the JOURNAL, consisting of approximately 18,000 numbers, is maintained for sale. Complete sets of the Proceedings of the Academy Vols. 1–13 (1899–1911), together with Directories, are also available.

Most of these volumes, including five reserve sets from Vols. 1–34, are stored without cost to the Academy in the Smithsonian Institution and the U. S. Coast and Geodetic Survey. Some of the volumes from Vols. 23–34 are stored by the George Banta Publishing Co. at Menasha, Wis.

SALES AND EXPENDITURES:

During the year 1944 three reserve sets were sold. These were purchased by libraries at the following universities: Notre Dame, New Mexico, and Mississippi. These were shipped via express, prepaid.

SALES

3 reserve sets	$504.00
Net sales of miscellaneous numbers	69.99
Total sales	$573.99

EXPENDITURES

2-year supply of postage and envelopes	$ 31.94
Express charges for shipments of 3 reserve sets of the *Journal*	20.89
1 year clerical assistance	10.00
Total expenses	$ 62.83
1944 Budgetary allotment	50.00
Excess over 1944 budget allotment (due to express charges)	12.83
Net gain for the year 1944	$511.16

FRANK M. SETZLER, *Custodian and Subscription Manager of Publications.*

Report of the Committee of Tellers

A total of 231 envelopes were delivered to the Committee by the Secretary. Of these, all bore a signature and each contained a ballot.

The count of ballots for officers of the Academy showed the following elected:

President, JOHN E. GRAF
Secretary, F. G. BRICKWEDDE
Treasurer, HOWARD S. RAPPLEYE
Board of Managers to January 1948, HENRY B. COLLINS, JR., and JAMES H. TAYLOR.

G. R. WAITE, *Chairman.*
W. D. URRY
C. A. WHITTEN.

Submitted by F. G. BRICKWEDDE, *Secretary.*